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DIFFRACTION HALOS IN NORMAL AND GLAUCOMATOUS EYES

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ABSTRACT. Every normal eye, under appropriate conditions, sees diffraction rings or halos encircling bright sources of light. Halos of a similar nature are seen by eyes in certain abnormal pathological conditions, particularly in the case of eyes suffering from glaucoma.

The practical importance of a more exact knowledge of the peculiarities of these halos was brought to the notice of one of the present writers at the instance of Lt.-Col. R. H. Elliot. The importance of the problem from the oculist's point of view rests upon the desirability of being able to differentiate with certainty between the halos seen by an eye in a normal condition and those seen by an eye suffering from glaucoma.

The present paper is an account of the results of some investigations into this problem carried out in the Applied Optics Department of the Northampton Polytechnic Institute, London.

I. DESCRIPTION OF COLOURED HALOS

WHEN a bright source of light of small dimensions is observed in a dark room or in any place where there is a tolerably dark background, certain characteristic phenomena may be noted. In the first place there are circular, black diffraction rings immediately surrounding the source and caused presumably by diffraction at the border of the pupil of the eye. Secondly, the source is surrounded by an immense number of narrow streaks of light radiating out in all directions from the neighbourhood of the source as centre; this appearance has been called the ciliary corona. Its extent and appearance vary with the intensity of the source. The radiating streaks show the various spectrum colours, these colours being brighter and the rays of the corona longer the greater the intensity of the source.

The cause of the corona has been ascribed to the fibrous structure of the crystalline lens (Tscherning[*]), and to diffraction at the border of the pupil (Helmholtz[†]), while observations by Dr C. V. Raman[‡], who used both white and monochromatic light, lead him to suggest that the phenomenon is due to diffraction by minute particles in the humours of the eye.

Thirdly, the source is seen to be surrounded by a coloured ring (or, on occasion, rings), showing a gradation of colours from violet nearest the source to red outside, the more prominent colours being the green and red. If the source be sufficiently bright, the ciliary corona extends beyond this ring.

II. HISTORICAL

A. *Normal Eye Halos*

(1) The appearances have been recorded by various observers, e.g. Tscherning, Sheard[§], Raman, Druault[||], Gullstrand[¶]. There seems to be general agreement as to the appearance of the ciliary corona. With regard to the coloured ring, also, most observers agree in stating the angular diameter of the yellow-green portion to be 6° or 7°.

A second, smaller ring of diameter about 3° for the blue has been described and called ring A by Tscherning; also Dr Sheard gives the size of a second, but in this case, larger and fainter ring he has observed, as varying from about 8° for the violet to 16° for red.

In describing the appearance of a ring of 6° to 7° in diameter, Druault and Salomonson[**] state that it seems to appear to everyone when the pupil is dilated and that it is irregular and composed of radial striae. Gullstrand also observed that this ring appeared to consist of many small fragments not exactly similar and both he and Morax[††] have asserted that although many persons naturally have pupils large enough to see the rings without help, others require mydriatics.

(2) In the accounts given by the various writers quoted of the causes of the rings seen by normal eyes, it is agreed that they are due to diffraction by some fine structure present in the eye media. The rings are somewhat similar in appearance to (although less bright than) those seen when a light source is observed through a diffracting screen such as a glass plate covered with lycopodium powder or a spiral or radial diffraction grating. In all these cases the innermost of the coloured constituent rings consists of light of the smallest wave length and the diameter of each coloured ring is approximately proportional to the wave length corresponding to that colour.

The phenomenon has been attributed to the cells of the epithelial and endothelial layers of the cornea (Sheard) and to minute structures in the cornea or vitreous humour (Raman).

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[*] M. Tscherning, *Physiologic Optics*, 2nd edition (English translation), p. 157.

[†] v. Helmholtz, *Handb. d. Physiolog. Optik*, 3rd edition.

[‡] C. V. Raman, *Phil. Mag.* (6), 38 (1919), 568.

[§] C. Sheard, *Amer. Journ. Ophth.* (3), 2 (March, 1919).

[||] A. Druault, see Morax, *Glaucome et Glaucomateux*, and Tscherning, *loc. cit.* p. 157.

[¶] Gullstrand, see Helmholtz, *loc. cit.* vol. 1, p. 192.

[**] H. Salomonson, referred to in Tscherning and Morax.

[††] V. Morax, *Glaucome et Glaucomateux* (1921).

Druault observed a ring of somewhat the same size as the smaller ring of Tscherning, which he states was due to the endothelium layer of the cornea; but with regard to the 6° to 7° ring he, in agreement with Gullstrand, Koeppe, Tscherning and others, traces its cause to the fibrous structure of the crystalline lens.

In support of this latter explanation as to the origin of the 6° to 7° ring, Druault describes an experiment in which an opaque screen was moved in a horizontal direction across the observing eye. When the forward (straight) edge of the screen reached a position just beyond the centre of the pupil of the eye, the portions of the coloured ring round about the extremities of a horizontal diameter disappeared, leaving only the top and bottom quarters of the ring visible.

In this connection it is instructive also to note the remarks of Gullstrand. He states that on passing a small *aperture* slowly across in front of the eye in a radial direction, he observed that when the aperture was central with the pupil the ring disappeared completely, but on reaching the edge of the pupil two small spectra were seen, the line joining these two spectra being at right angles to the direction of movement of the aperture. From this he concluded that the diffraction phenomenon (of the 6° to 7° ring) was due to a radial grating in the neighbourhood of the edge of the pupil such as is present in the cortex of the lens.

Brewster*, although he does not mention halos, refers to diffraction effects he observed by reflection from the surface of a crystalline lens and makes certain deductions from his measurements as to the size of the serrations of the edges of the crystalline lens fibres.

B. *Glaucoma Halos*

(1) Observations on the coloured halos seen by glaucomatous eyes appear to be less numerous. Gullstrand† states that they are larger in diameter than the normal eye ring. According to Tscherning, "the rings which glaucomatous patients see resemble these rings (normal eye) but are generally larger (10° to 11°)." From observations made over a lengthy period up to quite a recent date R. H. Elliot‡ gives the size as varying between 6° 50′ and 11° 54′ and alludes to variations between one eye and another and with the same eye at different times.

Sheard states their size to be 10° to 12°; whereas Morax§ gives the diameter as 4° to 5°, which is definitely smaller than the normal eye ring. There is thus a lack of agreement as to the size of the ring seen by a glaucomatous eye. The observations of Dr L. Koeppe|| are suggestive; he differentiates between a ring of diameter 3° to 3½° for red in glaucomatous corneal stasis without inflammation and "one of diameter 11° to 16° in the pre-glaucomatous and glaucomatous attacks of increased tension without any inflammatory signs."

(2) There is fairly general agreement in ascribing the cause of the glaucomatous halos to the formation of oedematous globules in the anterior layers of the cornea

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* A. Brewster, *A Treatise on Optics*, new edition (1831), p. 114.

† Gullstrand, *loc. cit.*

‡ R. H. Elliot, *Glaucoma: A text book for students of Ophthalmology*, 2nd edition, Oxford Medical Pub. 1921. This work contains a good general account of glaucomatous halos.

§ V. Morax, *loc. cit.*

|| L. Koeppe, *Amer. Journ. Ophth.* (3), 4 (Sept. 1921).

under the increased intra-ocular tension that accompanies the disease. Gullstrand and Morax describe the gradual decrease in intensity all over and the simultaneous disappearance of all portions of the halo, when an opaque screen is moved across the eye. The phenomenon is thus akin to that of the diffraction rings produced by a number of irregularly placed small circular obstacles or apertures, as in the case of a glass plate dusted over with lycopodium powder.

It is also stated that halos are seen by those aphakic eyes that become glaucomatous (Elliot), supporting the explanation that the cornea is the seat of the cause. The discrepancies between the sizes stated by different authorities may have some justification; it is permissible to suppose that the sizes vary according to the stage of the disease (*vide* Koeppe above). A statement made by Tyndall[*] lends weight to this view. He states "One of the most interesting cases of diffraction by small particles that ever came before me was that of an artist whose vision was disturbed with vividly coloured circles. He was in great dread of losing his sight, assigning as a cause of his increased fear that the circles were becoming larger and the colours more vivid. I ascribed the colours to minute particles in the humours of the eye and ventured to encourage him by the assurance that the increase of size and vividness on the part of the circles indicated that the diffracting particles were becoming smaller, and that they might finally be altogether absorbed. The prediction was verified. It is needless to say one word on the necessity of optical knowledge in the case of the practical oculist."

III. AUTHORS' OBSERVATIONS

As stated above, it is important for diagnostic purposes that the oculist be able to distinguish, with as much certainty as possible, between the coloured halos seen by a normal eye and those seen by a glaucomatous eye. Investigations have been carried out on both. Information regarding the latter can be obtained only from the person possessing the glaucomatous eye, and such cases, in this country at any rate, are not very numerous; moreover, the persons concerned are not skilled observers.

The results stated below with reference to normal eye halos are based principally on observations carried out by the authors themselves on their own eyes; the sizes of the rings, and their general character and behaviour, have, however, also been tested on numerous other eyes within the past few months, with similar results.

A. *Halos seen by the Normal Human Eye*

(1) The authors have not succeeded in observing more than one halo, except on rare occasions; in these cases the appearance of other rings was so fleeting that no definite remarks can be made upon them.

The one halo has been observed around various sources, such as the flame of an ordinary match or candle [illegible] of a luminous ophthalmoscope, an arc or "Pointolite" lamp behind a small aperture in an opaque screen. In all cases the surroundings were dark.

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[*] J. Tyndall, *Lectures on Light*, 2nd edition (1875), p. 92.

The intensity of the halo is very small in comparison with that of the source itself. (The intensity of the first of the series of diffraction rings caused by a circular obstacle, for example, is theoretically only $\frac{1}{57}$ of the intensity of the source itself.) Increasing the brightness of the latter, however, brings the ciliary corona so much in evidence that a point is reached when the halo is too faint in comparison to be seen. Even under the conditions found to be most favourable, the halo, in the authors' experience, is located only with careful attention, more especially when it is looked for deliberately with the intention of making measurements or other tests on it. Moreover, it is not always seen equally clearly by the same observer on different occasions, even when the surrounding circumstances are the same. It may be that this is due to variable physiological conditions; but it has been noticed that the pupil is usually small, perhaps after a tiring day, when the greatest difficulty is experienced.

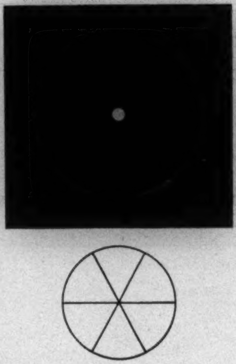


Fig. 1

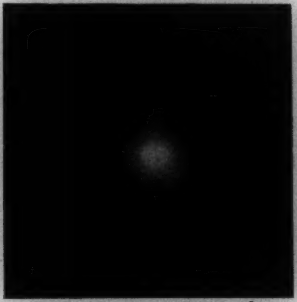


Fig. 2

Given good conditions, the ring is observed to be not exactly circular, nor of equal brilliancy at all portions. Six equi-distant portions, each of angular extent of roughly 20°, stand out somewhat more clearly than the remainder. Fig. 1 shows (not in colours, unfortunately) the ring seen by the left eye of E. F. F. on 3. xii. 21 and the corresponding position of the lens star of that eye, as found by placing near its anterior focal plane a minute source of light and so throwing upon the retina a shadow of the entoptic structures.

Fig. 2 is reproduced from the diffraction pattern produced by the crystalline lens of a sheep and photographed (12. x. 21); only the six portions of the halo are visible in this case.

These observations appear to suggest the possibility of the halo having some connection with the crystalline lens structure.

(2) *The size of the halo seen by the normal human eye.* The size of the halo was measured in a manner similar to that used by Young in his eriometer. The source, a 100 c.p. "Pointolite" lamp, was placed immediately behind a metal plate with a hole of 3 mm. diameter; at the extremities of a diameter of a circle of radius 2 cm., described around this hole as centre, were two further holes of 1 mm. diameter. By varying the distance of the eye from this plate, the two smaller holes can be made to coincide with any desired colour of the halo seen around the central hole. The lamp was enclosed to prevent illumination of the surroundings. In some cases this plate was fixed in the end of a postal tube within which telescoped a second tube, both blackened internally. In spite of the blackening, however, internal reflection was troublesome and subsequent observations were made in a dark room with nothing between the plate and the eye.

The results for the yellow-green constituent ring of the halo, from a number of readings with four different observers, are given in Table I.

Table I. *Halo—Normal Human Eye. Size for Yellow-green*

Observer	Angular diameter	Mean	Greatest spread
H. H. E.	6° 18′	6° 7′	22′
F. G. W.	6° 4′		
E. F. F.	6° 10′		
W. H. A. F.	5° 56′		

The authors made observations on quasi-monochromatic light by passing the light from a "Pointolite" lamp through a carbon disulphide prism and placing the centre of the eriometer plate in different portions of the spectrum successively. The results of these observations are set down in Table II.

Table II. *Normal Human Eye. Size and Colour*

Colour	Angular diameter
Violet	4° 30′
Blue	5°
Green	5° 26′
Yellow	6°

The relation between the size of ring and wave length of light forming that ring could be obtained somewhat more accurately by using monochromatic sources; but the ring observed is not clearly outlined and has an appreciable thickness, so that in any case the observer is called upon to estimate the mean position of the ring.

(3) *Effect of size of pupil.* The average size of the pupil in the above experiments was from 3 to 5 mm. diameter.

With an aperture less than 3 mm. diameter placed before the eye, the halo was not seen. The light entering the eye, it may be observed, covers in these circumstances a circle of about 2·5 mm. diameter on the crystalline lens.

The effect of dilating the pupil by cocaine to 9 mm. diameter was greatly to increase the intensity of the coloured rings and so to diminish the relative effect of the ciliary corona. No other effects were noted

(4) *Animal eyes.* A fresh bullock's eye, with a portion removed from the posterior, was mounted in a small glass dish with the axis vertical in such a way that the media were kept up in position relative to the cornea and the latter as nearly as possible at its natural convexity; a diffraction halo similar to the one seen by a human eye was found on a screen placed at an equivalent distance from the cornea of 35 mm.; the angular diameter of this ring was roughly 18° for the blue and 27° for the red.

This experiment was repeated with a fresh sheep's eye; the size in this case was roughly 12·5° for the red.

In the experiment on the bullock's eye the halo was not at all well defined, so that too much reliance cannot be placed on the figures for this eye.

The authors have produced the halo also by means of the crystalline lenses only of sheep and bullocks. In these cases the appearance was not a continuous circular halo; only six equi-distant portions of the spectral ring were visible. The effect is comparable with that of the human eye, the halo of which has six portions standing out more distinctly than the remainder, as stated above (see Fig. 2).

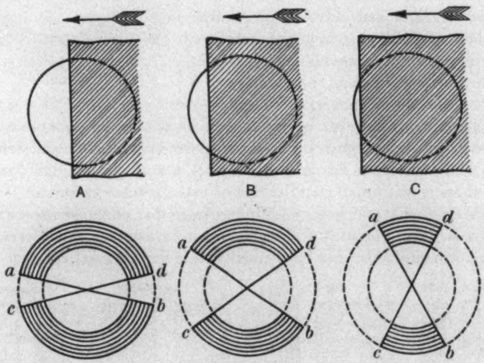


Fig. 3

(5) *Behaviour upon introducing a screen before the observing eye or grating.* Upon passing an opaque screen with a vertical straight edge horizontally before the eye, the phenomenon described by Druault was observed; namely, that when the forward edge of the screen reached a position a little beyond the centre of the pupil, the horizontal portions of the halo disappeared, leaving only the top and bottom portions.

Fig. 3 will assist in explaining this phenomenon. *A* indicates the appearance of the ring when rather more than half the pupil is occluded. In *B* less of the pupil is exposed and the missing portions of the ring *ac* and *db* have increased. *C* shows the screen exposing only the extreme edge of the pupil, in which case only the vertical extremities of the halo *ad* and *cb* remain.

The results tend to the conclusion that the halo is due to a structure that is of a more or less radial disposition, as in Fig. 4. For it will be readily seen, by passing a screen horizontally across the radial diagram (Fig. 4) that until more than half of the diagram is covered, radii in every direction are exposed so that the ring spectrum formed by a diffraction grating of this nature would not be affected, except in intensity. As soon, however, as the screen has passed the central position, we observe that the grating is deficient in vertical lines and therefore would produce no dispersion in the horizontal meridian; the appearance being as at *A* (Fig. 3).

As the screen is moved beyond this point, more and more of the lines are cut out until in the position shown at *C* only those lines approximating to the horizontal remain, producing two small arcs of spectrum in the vertical meridian.

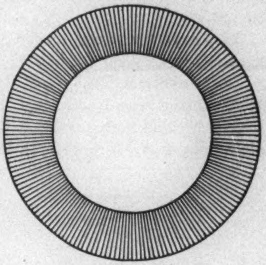


Fig. 4

Closer observation, however, revealed more than this; it was noticed that the two edges of a dark sector appearing in the ring were not equally well defined, and that whilst with some eyes the line *ab* rotating in a clockwise direction was the clearer, in others it was found that the line *cd* was the more distinct.

(6) Since this behaviour is quite different from that of the glaucomatous halo, and therefore is an important deciding factor as to whether an observed halo is normal or glaucomatous, further experiments were made.

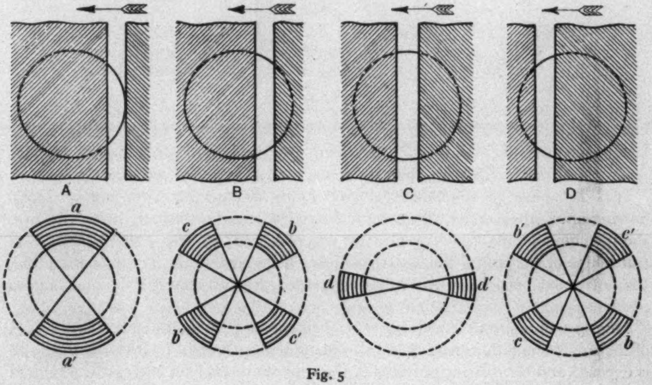


Fig. 5

A parallel-sided slit, 1 mm. wide (stenopaic slit), was passed before the eye. Preliminary observations confirmed that something of the same nature was happening. Closer attention revealed further detail.

Fig. 5 shows successive positions of the slit in front of the pupil with the corresponding appearances of the halo. In *A*, when only a portion at the border of the pupil was exposed, two portions *a*, *a′* of the halo were visible; upon moving the slit in a horizontal direction towards the centre of the pupil to the position indicated in *B*, the portions *a*, *a′* appear to divide, forming *b*, *c* and *b′*, *c′*. These portions rotated, *b*, *b′* in a clockwise direction and *c*, *c′* anti-clockwise, as the slit was moved still further. With the slit central, as in *C*, the portions appeared to reunite into *d*, *d′*. Upon continuing the motion of the slit, *d*, *d′* appeared to divide into portions *b′*, *c* and *c′*, *b*, the rotation continuing as before until finally these latter amalgamated as at *a*, *a′* in *A*, when the slit was at the other extreme position.

These are the results that would be expected from a radial structure. If a narrow slit be passed across the diagram in Fig. 4 it will be seen that the portions successively exposed are such as would produce spectra in the positions indicated in Fig. 5.

(7) It was further noticed that of the four portions, one pair, either *b*, *b′* or *c*, *c′*, was constantly more distinct than the other pair, for a given eye. The pair pronounced to be the more distinct by one eye was not necessarily so for another eye.

The experiments were repeated, with the slit horizontal and moved in a vertical direction, with similar results.

These results are collected together in Table III. The directions in columns 3 and 4 are the directions in which the more distinct pair of spectra moved (C = clockwise, A = anti-clockwise).

Table III

Observer	Eye	Slit vertical moved horizontally ←	Slit horizontal moved vertically ↓
E. F. F.	R	C	A
	L	C	C
H. H. E.	R	A	A
	L	C	C
F. G. W.	R	A	C
	L	C	A

It thus appears that the halo seen by the normal eye is due to a structure which is, or has the property of, a radial structure, extending to within a millimetre or so of its centre. Moreover, the last series of experiments indicates that the fibres are more in evidence at some portions of the periphery than at others. The fact that one of the two pairs of the spectra is brighter than the other would be accounted for if the structure were not equally perfect all round.

The same results would follow too, if the pupil that is admitting the light to the system of the eye were displaced perpendicularly to the common axis relatively to the radiating structure.

If, for example, the entrance pupil *E* is displaced relatively to the diffracting structure *A*, as in Fig. 6, then the one pair of spectra at the top and bottom, due to the fibres in the neighbourhood of *a*, would divide into two pairs when the slit reached such a position as to expose fibres in the neighbourhood of *b* and *d*; and of these two pairs, the one due to the fibres at *d* would be brighter than that due to the fibres at *b*. As the slit was moved across in a horizontal direction from right to left, the brighter pair would rotate in a clockwise direction.

The known arbitrary relative displacement of crystalline lens and pupil would appear to be connected with this phenomenon; such investigations as the authors carried out did not, however, establish definite conclusions on this point.

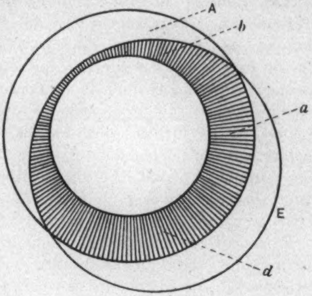


Fig. 6

Bearing in mind that, at least under the conditions used by the authors, the complete halo was not visible in the case of the crystalline lenses of sheep and bullocks, the behaviour under the slit test was of the same order. When the slit (vertical) occupied the peripheral position in front of the crystalline lens, of the six small spectra those portions at the extremities of the vertical diameter alone remained. With the slit central, only the horizontal portions remained.

B. *Halos seen by Glaucomatous Eye*

(1) The source of light used was a 20 watt frosted metal filament lamp, placed behind a small aperture of 5 mm. diameter in a screen in a dark room at a distance of about 2 metres from the patient. In each of the cases tested, one of the several symptoms complained of was the presence of "coloured rings round lights." These are not always seen, but only just before or during the attack, which may last for a period of several hours. During the period when the halos were in evidence, the ocular tension was found to be high, and the cornea had a slightly misty appearance. Other symptoms, such as severe headaches, etc., are not of primary importance to this investigation.

The intensity of the halos varied to some extent on different occasions with the same patient, but at the height of the attack they always were of far greater brightness than those seen by the normal eye. The ciliary corona was scarcely visible, the space between the source and the blue ring being dark grey, scarcely distinguishable from the blue, which one patient described as royal blue. The ciliary corona, however, became much more evident when a more intense source was used.

(2) The angular diameter of the halo was measured in substantially the same manner as the normal eye halo above. A small, not very bright, electric lamp was moved in front of the screen radially towards the source until it coincided, first

with the outermost (orange) constituent ring seen by the patient and then by each coloured portion of the ring in turn.

The average of a number of such measurements is given in Table IV; the table gives the angular diameter in degrees.

Table IV

Colour	Patient *A*	Patient *B*
Blue	4°	4 to 5°
Green	5° 26′	6°
Yellow	6° 18′	6° 54′
Orange	7° 26′	8°
Orange-red	9° 26′ extreme edge	8° 36′

The measurements appear to indicate that there is a small difference in size of the halos as seen by different eyes; a difference which, though small, cannot be neglected. Moreover, there were indications that the size of the ring varies at different times with the same patient.

(3) Upon passing an opaque screen in front of the eye, the ring was stated by the patient to decrease in brilliancy and finally disappear, all portions of the ring disappearing simultaneously.

On one occasion a second halo, concentric with the first, was stated to be visible, but was too faint for measurements of its size to be made. This patient stated that on occasions three concentric halos are visible.

IV. CONCLUSIONS

Although this interesting problem has not by any means been exhaustively treated here, certain conclusions, of practical use to the oculist, emerge.

A. *Normal Eye Halos*

The halo, except on rare occasions when all circumstances as to brightness of source, surrounding darkness, etc., are favourable, is seen only with difficulty and with previous knowledge as to its existence.

The size is approximately constant in all normal eyes at rather more than 6° angular diameter for the yellow ring.

The results of the observations indicate the crystalline lens as being the cause. When an opaque screen or slit is moved across the observing eye, only portions of the halo disappear, the remaining portions moving round the circle as the screen or slit exposes different portions of the pupil.

B. *Glaucomatous Halos*

The halo, when seen, varies in brightness at different periods of the attacks but is always appreciably more vivid, and usually far more so, than the normal eye halo.

The size also appears to vary at different stages of the disease, so that size alone cannot be accepted as a criterion of the differentiation between glaucomatous and normal halos.

When an opaque screen is moved across the eye the halo behaves as those formed by a number of equal small particles; that is, the halo gradually decreases in intensity and finally disappears simultaneously all over. Evidence points to the cause being a formation of oedematous globules in the tissues of the cornea due to the increased intra-ocular tension.

It thus appears that there are definite differences between the glaucomatous halo and the normal eye halo: firstly, the glaucoma halo is much brighter than the normal eye halo; secondly, the "slit test" produces different phenomena in the two cases.

Much interesting information with regard to the structure of the eye and these entoptic phenomena could doubtless be obtained from further research on these lines. Experiments are in progress and, it is hoped, will form matter for a subsequent paper.

DISCUSSION

Lt.-Col. R. H. Elliot (communicated): It has long been well known that an eye suffering from the disease known as glaucoma is liable to see coloured halos around lights, and that these halos are diffraction phenomena. It is less well known that coloured rings, which may be mistaken for those which occur in glaucoma, may be seen under a variety of conditions by quite normal eyes, and that anything which dilates the pupil of the eye makes it easier for such rings to be seen. The phenomena of "rainbows round lights" is well known to glaucomatous patients, and through them to a large section of the public. Moreover it is a very arresting symptom, and one which is not only easily observed, but which at night time forces itself upon the attention and is apt to give rise not unjustly to feelings of serious alarm.

It must be obvious from these considerations that it is a matter of great importance to ophthalmic surgeons to be able to distinguish clearly between what are sometimes called "the true halos of glaucoma" and physiological halos. It is true that no surgeon should or would operate on the strength of one sign alone; he would take the whole case in its entirety, but all the same he might be strongly prejudiced by so outstanding a phenomenon as this undoubtedly is. It would be no small misfortune if he were induced to undertake an operation, or even to place a patient on a prolonged course of treatment for glaucoma, when the disease is not actually present. There is yet another point. As surgeons we often have to use drops which dilate the pupil, and not a few people will see distinct halos under such conditions. I have already said that the public are familiar with halos as a sign of glaucoma. Many of them also know that an attack of glaucoma may be precipitated by the artificial dilatation of the pupil as a result of the use of drugs. You will see from all this how essential it is that we should be able to distinguish clearly between the true halos of glaucoma and those which imitate them.

I have for a long time been interested in this subject, and through the courtesy of Mr Beck I came to know of Mr Emsley, to whom I put my difficulties. He and Mr Fincham, working together, have devised a test whereby the true halos of glaucoma and the false or physiological ones can be easily distinguished. Their test turns on a very simple physical fact, viz., that the glaucoma halos are due to diffraction of the light by globules of fluid which collect in a portion of the cornea or clear window of the eye as a result of the obstruction to the circulation in this membrane caused by glaucoma. The physiological halos, on the other hand, have been shown by their phenomena to be due to diffraction at a radial grating. It has long been known anatomically that the arrangement of the fibres in the lens of the eye is such as to constitute this structure a radial grating. Fortunately for us diffraction at this radial grating is not a very active phenomenon in the majority of people, though it apparently becomes more active as life advances. There is also strong reason to believe that the peripheral parts of the lens constitute a much more active diffracting medium than the central part. As is well known, the pupils contract in a bright light, and in doing so cut off the lens periphery and so save us from unpleasant diffraction phenomena. If, however, the pupil is naturally widely dilated, or is so dilated by the use of drugs, or if again, a portion of the iris of the eye has been removed, thus exposing the periphery of the lens, the physiological halos may become much more pronounced and lead to unpleasant symptoms, and so to deep anxiety on the part of the patient and even of the surgeon.

So little has been known on this subject that I feel that we are under a great debt to Messrs Emsley and Fincham for having devised a test whereby we can so accurately distinguish between the true halos of glaucoma and those which imitate them.

One last word—the true halos of glaucoma vary widely in diameter. I have measured a number of them, and have found that the angular measurements of these rings may vary from under 7° up to nearly 12° and that they may vary in the same patient from time to time. This is undoubtedly due to corresponding variations in the diameters of the tiny fluid particles which give rise to the diffraction phenomena. It is probable that at an early stage the fluid particles would be small, and the rings consequently large; at a later and acute stage the fluid particles would be at their largest and the rings therefore at their smallest; lastly, as the disease is passing off the fluid particles would again become small and the rings would increase in diameter. On the other hand, the physiological rings, which are the result of diffraction by the fibres of the lens, are constant in size (7° to the outer orange red ring), for the simple reason that, within certain margins, the lens fibres are constant in diameter. This furnishes another easy and satisfactory test in many cases.

Dr E. Claude Taylor said that the new tests suggested by the authors were proving very valuable. He mentioned the case of a patient of his who, subsequent to a successful operation for glaucoma, was very much worried because the halos persisted; the surgeon was led to think that a further operation might become necessary. The authors had applied their tests and found that the patient described the phenomena exactly on the lines of the lens diffraction halos, there being no actual condition of glaucoma present.

Lt.-Col. H. Kirkpatrick stated that halos were an undoubted source of annoyance to patients. He had personally experienced them on one occasion when his pupils had been artificially dilated. He drew attention to causes of the appearance of halos other than glaucoma and lenticular diffraction. A thin film of blood, spread over the surface of the cornea by the movements of the lid, may cause the phenomenon owing to diffraction by the blood corpuscles; this may occur in India where chicken's blood is sometimes used by quacks as an application to the eye on account of its supposed "cooling" property. Muco-purulent discharges may act in the same way, and halos have been observed to follow the application of caustics, such as nitrate of silver, to the conjunctiva; in such a case some of the fluid may reach the corneal epithelium and, by causing degenerative changes in it, lead to diffraction.

Dr M. Dobson drew attention to a number of other conditions of the eye which give rise to halos.

Dr E. E. Maddox (communicated): The authors have proved their points very lucidly. Those of us who are engaged in the multitude of subjects which comprise ophthalmology have little time for the uninterrupted study of pure science and it seems a capital idea for the Northampton Institute to be utilised for such work.

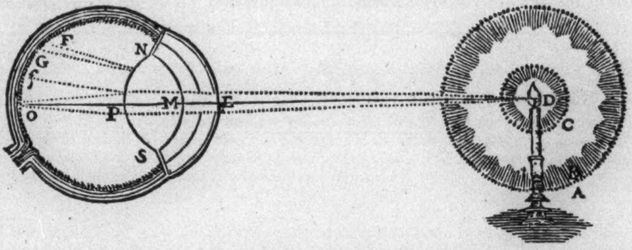
The optical packing between the lens fibres is evidently more perfect in the central portions of the lens, and Nature has not been so careful about it near the periphery, for in ordinary life the pupil contracts sufficiently when a strong light is looked at. In the human body provision is never made when no need for it exists. The diagrams prove the radial fibrillation of the lens beautifully, and it is quite beyond doubt that physiological halos are lenticular.

I look on glaucomatous halos as due to *subepithelial sweating of the cornea*, raising the epithelium into multitudes of tiny hillocks, rather than oedematous globules in the proper substance of the cornea, which latter would not, I think, have the effect. Stretching of the cornea might conceivably contribute also by dislocating the fibres from their optical packing and, since they run in all directions, the phenomena produced by a screen passing across the cornea would differ entirely from the lenticular ones and resemble those so well known in glaucoma.

Prof. Cheshire said that the paper was of special interest, as it was the first contribution to the Society from the Ophthalmological Research Laboratory of the Northampton Polytechnic Institute.

The diffraction phenomena which the authors had described agreed in every detail with the experiences of those who had examined such phenomena in microscopy.

Mr W. H. A. Fincham: It may be of interest from a historical point of view to notice that Descartes in his *Discours de la Méthode*, dated 1637, gives an account of the coloured coronas seen around flames and lamps, and shows that they are produced, not by the air, but by the eye which sees them. He describes how after resting at night with his right eye upon his hand, when a lighted candle was brought to him, he saw with his right eye the coronas *AB* and *CD* around the flame, as depicted in the figure photographed from his book. "Their colours," he says, "were as bright as I have ever seen them in the rainbow." Descartes' attempt to explain the phenomenon is not very enlightening, except that he realised that his eye had acquired some altered disposition whilst he pressed upon it. He suggests that one or two circular wrinkles may have been formed in the surfaces of the eye marked *E*, *M*, *P*, or again that the humours or membrane of the eye have in some manner changed in constitution or shape; "for," he says, "it is common to those who have diseased eyes to see such coronas, and they do not appear similar in all cases."



Mr C. L. Redding: The difficulty in seeing the physiological halo is largely due to the smallness of the pupil. Although the pupil of my own eye is small I can see a distinct break in the halo on passing a slit in front of the eye, provided the latter has been dark adapted for about five minutes There is no reason why opticians should not apply the straight edge and slit tests in the case of patients who are suspected of having glaucoma. It is desirable that ophthalmic surgeons and opticians should co-operate more closely and discuss problems of mutual interest.

Authors' reply (communicated): The kind of halos referred to by Lt.-Col. H. Kirkpatrick and Dr M. Dobson are well known. They are caused by the formation in some manner, either natural or artificial, of a broken film on the outer surface of the cornea. The halos thus disappear when this external film is removed (which can usually be done in a moment), indicating at once that they are not due to glaucoma or to the crystalline lens.

The authors have carried out tests on such halos by introducing a drop of blood into the conjunctival sac, the resulting halos being marked but not of any special significance. For a period during the summer of 1921 one of the authors could see a halo each morning, due to mucus having formed on the cornea; it became broken up at the first blink or so of the eyelids. The opportunity was taken of roughly measuring the size of this halo which was found to have an angular diameter of 14° for the red ring.

The paper was intended to show the difference between the normal or physiological halos and those due to glaucoma; these are caused by structures *inside* the eye.

Dr Maddox's view of the cause of glaucomatous halos, namely, as being due to the raising of the epithelium into tiny hillocks by the subepithelial sweating of the cornea, is very interesting. The fact of this being the case would not, as he points out, affect the fundamental difference between the two classes of halo that are the subject of the paper. The authors assumed, without making any investigation on the point, the correctness of the generally accepted view that glaucoma halos are due to the oedematous globules themselves. The authors are pleased to have called forth this view of Dr Maddox's, and think that probably it is worthy of investigation.

THE EFFECT OF CHANGES OF SURFACE CURVATURE AT THE FOCUS OF AN ASTRONOMICAL OBJECT GLASS

By E. WILFRED TAYLOR
(Messrs T. Cooke & Sons, Ltd., York)

MS. received, 27th January, 1922. Read and discussed, 6th April, 1922.

ABSTRACT. The correct balancing of the components of a large object glass is necessarily a lengthy and difficult process, and the effect, at the focus, of a similar alteration of curvature at each of the four surfaces, is different. If the effect of an alteration at each of the surfaces is known, the one most suitable may be chosen, having regard to the amount and nature of the aberration it is necessary to overcome.

For a large object glass the curves are accurately computed to eliminate spherical aberration and to bring the C and F rays to a common focus; thus in the case of an object glass of 6-inches aperture the constants of the two discs are

$$\text{Ordinary crown, } \mu_D = 1\cdot5166 \text{ and } \frac{\mu_D - 1}{\mu_C - \mu_F} = 60\cdot56273,$$

$$\text{Ordinary flint, } \mu_D = 1\cdot6132 \text{ and } \frac{\mu_D - 1}{\mu_C - \mu_F} = 36\cdot91732.$$

Taking the radius of curvature of the fourth surface (the surface through which the light passes last) as -180 inches, the curves come out as follows:

Crown lens $+ 29\cdot1605''$ and $+ 48\cdot2695''$, thickness $\cdot50''$.
Flint lens $- 43\cdot9847''$ and $- 180''$, thickness $\cdot40''$.

With an air gap of ·10 in. between the two lenses, the marginal rays cut the axis ·0043 in. farther from the back surface than do the axial rays. The object glass is therefore very slightly over-corrected for spherical aberration. The combined focal length is about 90 ins.

If an object glass was made exactly to these curves there would be little residual aberration to balance, but in practice the nearest tools will have to be used and when the object glass is first examined as a whole, it will show marked over- or under-correction—this must be rectified by suitable alteration to the surfaces. To make a new set of tools is not usually worth while as the next discs will probably have different optical properties or a different focal length may be required for the object glass.

The deep surface of the negative lens is first figured until it is as perfect as possible when examined by back reflection, and the shallow surface is made deeper or shallower until the colour correction is approximately correct. (If the O.G. as a whole is under-corrected for aberration the colour should also be slightly under-corrected and *vice versa.*) Any irregularity of figure or any spherical aberration must now be assumed to be due to the positive element, where it must be corrected, but where it cannot readily be detected by direct examination as in the case of the negative surface.

At this stage the object glass will show more or less spherical aberration, depending on the departure from the theoretical curves, and this must be corrected by suitably altering one or other of the positive surfaces; that is by deepening or shallowing the surfaces, as the case may be. The new curve may not be truly spherical but will not in general depart appreciably from a spherical curve. These alterations to the crown lens will have a slight effect on the colour corrections. The colour correction can be finally perfected without any appreciable effect on the spherical aberration.

At this stage it is necessary to decide which of the two surfaces of the crown lens to select for alteration. In practice it is found that the inside surface of the crown lens exercises, for a corresponding change of curvature, a greater effect on the spherical aberration (and in consequence a smaller effect on the colour) than does the deep outside surface. At this stage one feels the desirability of knowing definitely what is the effect at the focus of a given change in power at any one of the surfaces, with a view to choosing the one most suitable for the purpose in view.

In polishing, the maximum alteration to a curve will be about half the spacing between one tool and the next and $\frac{1}{r} \pm \frac{1}{2000}$ may be taken to represent the limits likely to occur in practice, where r = radius of curvature. The limits for each surface will then be:

	(*a*)	(*b*)	(*c*)	(*d*)
Maximum	+ 29·59198″	+ 49·46327″	− 44·97383″	− 197·8022″
Correct	+ 29·16052″	+ 48·26950″	− 43·98466″	− 180″
Minimum	+ 28·74146″	+ 47·13197″	− 43·03815″	− 165·1377″

In order to determine the effect, at the focus, of an alteration in power of each surface, from a maximum to a correct value and from a correct value to a minimum value, the other three surfaces were left unchanged at their correct values. The linear value of the spherical aberration was worked out trigonometrically, the slight over-correction of ·00434″ in the case of the calculated values being allowed for in each case.

Denoting over-correction by a + sign and under-correction by a − sign, and taking the four surfaces in the order that the light traverses them, we get:

(*a*) First	surface	maximum	radius	+ ·01198″	average	·01309″.
,,	,,	minimum	,,	− ·01420″		
(*b*) Second	,,	maximum	,,	+ ·04546″	,,	·04554″.
,,	,,	minimum	,,	− ·04562″		
(*c*) Third	,,	maximum	,,	− ·05820″	,,	·05555″.
,,	,,	minimum	,,	+ ·05290″		
(*d*) Fourth	,,	maximum	,,	− ·00414″	,,	·00369″.
,,	,,	minimum	,,	+ ·00325″		

Taking the effect of an alteration at the fourth surface as unity the figures expressing for the four surfaces the average amount of the spherical aberration produced at the focus are 3·54, 12·34, 15·06, and 1. It will be seen that to produce a given alteration at the focus, a much greater alteration will be required at surface (*a*) than at surface (*b*) and very much more at surface (*d*) than at surface (*c*). It will also be seen that the effect on the spherical aberration of an alteration to surface (*d*) is only negligible when the alteration is slight.

From these figures we may deduce the best procedure, in the correcting of a large object glass, as follows:

(1) Correct the figure of the third surface, making it as perfect as possible.

(2) Alter the radius of the back surface until the O.G. as a whole is about correct for colour. If the object glass is under-corrected for aberration the colour correction should also err on the underside. Obtain a perfect figure.

(3) Approximately correct the spherical aberration on the second surface of the crown, where the effect is comparatively great. Alteration at this surface has the least effect on the colour for a given change in the spherical aberration, the proportional alterations to colour for the four surfaces for the same alteration of spherical aberration being − 3·48, 1, 1·34, and 20·24, where that of the second surface is taken as unity.

(4) Obtain final perfection by alteration to the first surface.

(5) If necessary, re-correct the colour by alteration to the fourth surface and again obtain a perfect figure. The correction for spherical aberration will be unaffected as the alteration will be slight.

In this paper it has been assumed that the focal length can vary and it is improbable that the final focal length will be 90″ as it was in the case of the calculated curves. Generally a change of one or two inches is immaterial but if an object glass is required to have a certain focal length, within small limits the procedure will be different and it may have finally to be obtained by slightly modifying the colour correction.

It is an interesting fact that, although it is the aim in designing an object glass *of this type* to bring the C and F rays to a common focus, this cannot be perfectly accomplished. If, for instance, the axial C and F rays meet at a common focus, then those that pass through the margin of the lens cannot do so. This is due to the fact that if the D rays are perfectly corrected for spherical aberration, the C rays will be under-corrected and the F rays over-corrected. Probably the best colour correction possible consists in bringing together the circles of least confusion for the C and F rays.

In the case of the object glass considered above, when the D rays are perfectly corrected for spherical aberration, the linear under-correction for the C rays is − ·00424″ and for the F rays the linear over-correction is + ·01606″.

DISCUSSION

Mr T. Smith (communicated): This paper is particularly interesting in that it gives the procedure in correcting objectives which the very extended experience of Messrs T. Cooke & Sons has shown to be most satisfactory. If numerical evaluation of the effects of known curvature alterations is not required, but it is merely desired to find which surface should preferably be altered, a decision can be reached on quite general grounds. The alteration of a single surface may be regarded as (1) a change in the power of a component without a change in the shape, together with (2) a change in the shape without any change in the power. This way of regarding the change is equivalent to resolving any displacement of a point into two components in assigned directions; the point of intersection of the two surfaces in any diametral section when the curvature of one surface is altered moves along the other surface; (1) corresponds to a displacement towards or away from the axis, and (2) a displacement parallel to the axis. The effects of (1) are the same whichever surface is altered, but the effects of (2) are dependent in sign upon the surface selected. The chromatic aberration is determined solely by (1), but spherical aberration is dependent upon both, and consequently the greatest change in spherical aberration for a given change in chromatic aberration is obtained by altering the side for which the two contributions to the change in spherical aberration agree in sign. The sign of the change due to (1) is evident, and the change in spherical aberration under (2) has the same sign as the power of the component lens when the lens is bent further away from the form for which the aberration is a minimum. In the present case if the colour is over-corrected the power of the crown lens must be increased, and the contribution to spherical aberration under (1) is positive. To obtain a positive contribution from (2), the crown lens must be made less near the "crossed" form, that is to say, the second surface must be altered. If the colour is under-corrected, all changes must have their signs reversed, and the surface to be altered is not affected.

Mr S. J. Underhill thought that the procedure outlined by the author was applicable only to lenses having an aperture ratio of less than F/9, and that lenses having greater aperture ratios must have their surfaces deformed from the spherical shape to correct for spherical aberration. This process can be exactly performed by utilising a special instrument*, in which both the amount of glass to be removed and the zone upon which the removal is to be made are seen at the same time. The correction can then be quickly and accurately performed by a skilled worker.

Mr H. S. Ryland said that some years ago Mr Max Zwillinger had constructed objectives which fulfilled the sine conditions and were free from spherical aberrations. He obtained good results by figuring the back surface, but the process was very expensive.

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* *Trans. Opt. Soc.* 22 (1920–21), 174.

Author's reply (communicated): General methods, such as the one given by Mr Smith for deducing the effect at the focus of an object glass due to changes at the surfaces, are extremely useful. It is chiefly in the case of large surfaces, where the cost of figuring is high, that general considerations are not sufficient.

The aperture ratios, for which these results were intended to apply, vary between F/10 and F/15.

In reply to Mr Ryland, I should like to say that this firm has frequently made object glasses that both fulfilled the sine condition and were free from spherical aberration. These are usually supplied with Transit Instruments where a large field is required.

POLARISCOPES: A FEW TYPICAL FORMS OF EARLY INSTRUMENTS IN THE SOUTH KENSINGTON MUSEUM

By Professor F. J. CHESHIRE, C.B.E., F.Inst.P., P.R.M.S.

At the meeting of the Optical Society on Nov. 27, 1921, a large number of early and interesting instruments from the Collection at the South Kensington Museum was exhibited by kind permission of Colonel Lyons, the Director of the Museum. Of these instruments a few of the more interesting and typical specimens have been selected for illustration and description.

Historical note. In the earliest forms of polariscopes, brought into existence by the discovery of Malus in 1808 of polarisation by reflection, the polariser was usually a single sheet of black or blackened glass. The analyser again was either a single plate of glass, similar to the polariser, or a simple rhomb of Iceland spar giving a double image, in the well-known way, of the crystal or other object under examination. This type of instrument, however, was practically used for examination in parallel light only, although Brewster states that with the arrangement of two reflectors he discovered the axial ring system of uni- and bi-axial crystals in 1813, a discovery which appears to have been first published by Biot in 1815. The general use of the polariscope with so-called convergent light dates from the discovery of Biot in 1815 of the peculiar property of tourmaline plates cut parallel to the axis of the crystal. These plates, if of sufficient thickness, polarise by absorption, that is, one of the two polarised beams into which the incident light is split is transmitted, whilst the other is absorbed. Two such plates mounted so that one can rotate upon the other form what are known as tourmaline pincettes or tongs. When an axis-cut plate of crystal is placed between the tourmalines, the instrument permits of examination in converging bundles of polarised parallel rays originating, it may be, in light from all parts of the sky.

The design of polarising apparatus was finally greatly improved by the invention of the nicol prism by Nicol in 1828. In the succeeding half century the subject received an extraordinary amount of attention, and important applications to technical needs were invented.

The evolution of the polariscope in its various forms, including that of the petrological microscope, owes much to the work and ingenuity of Nörrenberg (1787–1862). He it was who overcame the difficulty of observing the ring systems of crystals, due to the small angular field of view possible with such contrivances as tourmaline tongs. He did this by placing the crystal plate to be examined between two short-focus condensing systems of lenses of great angular aperture, and separated by a distance equal to the sum of their focal lengths, so that bundles of parallel rays passing through the crystal at different obliquities were brought to a focus in the upper focal plane of the upper system to give the ring system as in the petrological microscope.

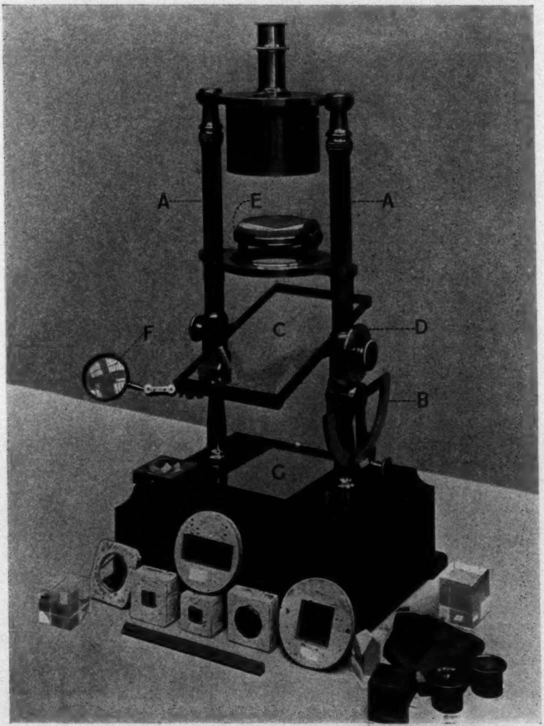

Fig. 1. Early form of Nörrenberg's polariscope.

Fig. 1 shows one of the earlier forms of Nörrenberg's polariscope, as made by Lutz of Paris*. The instrument consists of a square wooden base, carrying extensible jointed pillars *AA*, which can be tilted to any angle read off on a scale *B*. A single plane glass plate *C* is mounted to rotate about a horizontal axis through an angle read off on a graduated circle *D*. When the instrument is in a vertical position, the plate *C* is tilted to make an angle of 56½° with a horizontal plane. Light incident upon its under surface, and reflected vertically downwards is then plane-polarised by reflexion. This light is reflected upwards again by a horizontal mirror *G* on the top of the base, thence through the plate *C* to the eyepiece which consists of a simple nicol prism. The object is placed upon a circular glass disc *E* mounted to rotate about the axis of the instrument, and also about a horizontal axis. The angular displacements in both cases can be read off on graduated scales. For

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* An important modification of Nörrenberg's apparatus was devised by Wheatstone in 1871, for carrying out experiments with elliptically and circularly polarised light produced by reflexion from a silver plate.

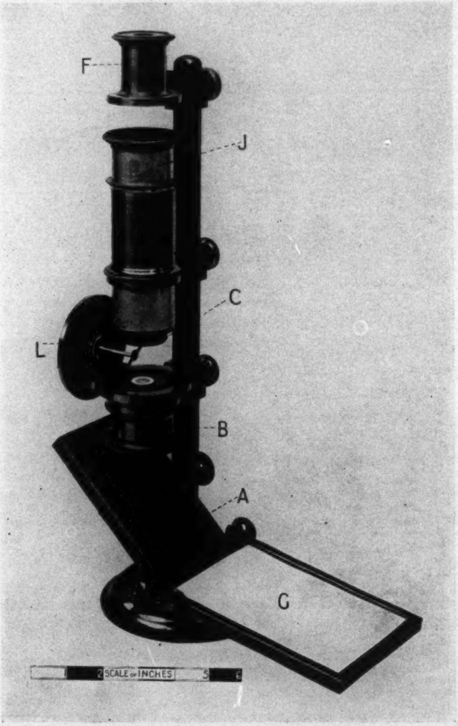

Fig. 2. Later form of Nörrenberg's polariscope.

examination in convergent light the object is placed on the surface of the horizontal mirror with the converging lens *F* immediately above it.

Fig. 2 shows a Nörrenberg polariscope of a later type, as made by Steeg and Reuter; Fig. 3 shows the optical system of the same to scale. The reflecting polariser *A* receives light from a more or less horizontal reflector *G*. The polarised beam passes through a pair of lenticular condensing systems *B* and *C* of the Abbe type, and the interference figures are observed in the upper focal plane of the upper condenser in the usual way, by means of a simple magnifying lens, carried by a sliding tube *J*, and an analyser *F*, in a separate mount fitted with an angular scale. All the fittings are adjustable on a vertical bar of square section, to which they are clamped. The object under examination may be attached to a goniometer *L*, and

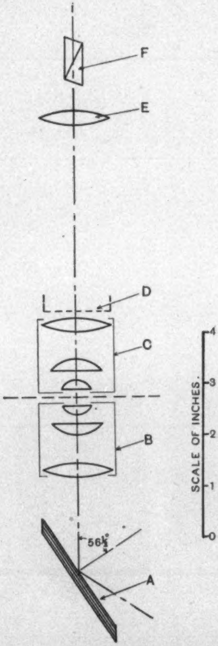

Fig. 3. Optical system of Nörrenberg's polariscope.

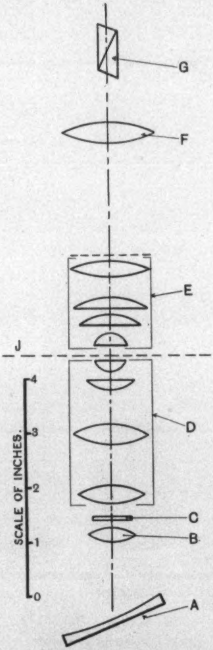

Fig. 4. Optical system of polari-microscope (Hofmann—Paris).

thus tilted as required with respect to the axis of the polariscope. The optical system shown by Fig. 3 is interesting on account of its simplicity. Each of the condensing systems consists of three lenses, as shown, with an equivalent focal length of 0·75 inch. Cross-wires are mounted in the upper focal plane of the upper condensing system *C*, and the interference figure in this plane is examined in the usual way by means of the magnifying lens *E*, with a focal length of 4 inches, and the analyser *F*. The angular aperture of each of the condensers is about 110°.

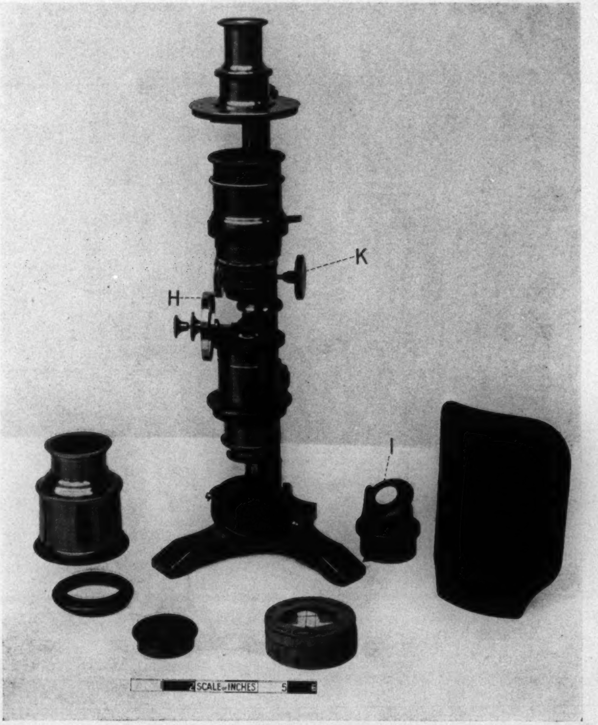

Fig. 5. Another later form of Nörrenberg's polariscope.

Fig. 5 also shows a Nörrenberg polariscope, as made by Hofmann of Paris, which is interesting because of (1) its optical system, and (2) the fact that the polariser is a plate of tourmaline. The general design of the instrument is similar to the one referred to above. The various parts are mounted in tubes collimated by attachment to a vertical pillar. The object also, as before, may be carried by a goniometer *H*, or alternatively upon a tilting ring *I*, which is also free to rotate in azimuth. The optical system, shown by Fig. 4, consists of a concave reflector *A*, with a radius of curvature of 6 inches, which, in combination with the lens *B* of 1·5 inches focal length, focusses a distant light source, such as the sky, in the plane of a plate of tourmaline *C*, which has a diameter of about 0·75 inch. The condensing system *D*, consisting of the four lenses shown, projects an image of the tourmaline *C* and also therefore of the distant light source into the object-plane *J*. The upper condensing system *E*, which can be racked up and down by the pinion *K* (Fig. 5), has a focal length of 0·63 inch, and an angular aperture of 160°. The interference figure in the upper focal plane of this condenser is examined by means of a lens *F* (Fig. 4), with a focal length of 3 inches, and an analyser *G* in the usual way.

This instrument illustrates in a striking way one of the most serious defects of the early forms of polariscopes—the large number of reflecting air-glass surfaces. In the system just described, it will be seen, twenty-five of these surfaces occur, and when it is remembered that tourmaline itself cuts down the incident light to very much below one-half of the total light incident upon it, the seriousness of the objection will be appreciated.

Fig. 6 shows a projection polariscope of the type invented by Duboscq in 1875, and made by Ladd. Fig. 7 shows one arrangement of the optical system of the same. The instrument consists of a tripod carrying a tilting base-bar *F*, upon which the parts are adapted to slide and be clamped. The tube *G* carries a pair of double-image prisms, *B* and *C*, which when similarly oriented give an angular separation of the polarised beams of about 5°. One of these beams, in general, passes axially through the system, whilst the other is thrown to one side. The tube *H* carries a condensing lens *D*, a projection lens D_1, and an analyser *E*. A pair of forceps, one jaw of which carries a condensing lens, is mounted on the end of an arm *I*, and can be thrown into the axial line of the instrument as required to work in combination with an auxiliary condensing lens, mounted in an arm *J*. A mica quarter-wave retardation plate may be mounted inside the analyser *E*, to be rotated, as desired, through an angle of 180°.

Duboscq's projection apparatus is used in different ways for different purposes. For projection with parallel polarised light (*lumière divergente* (Duboscq)) the light from an arc, or incandescent lime, is rendered parallel by a condenser in the usual way, and then brought, by a lens *L*, to a focus in a small aperture in a plate *K* mounted in the inner end of the tube *G*. In passing through the pair of double-image prisms, however, the beam is divided, with the result that one image only is projected into the axial aperture, the second beam being stopped. The object is placed against the lens *D* and projected with the lens D_1.

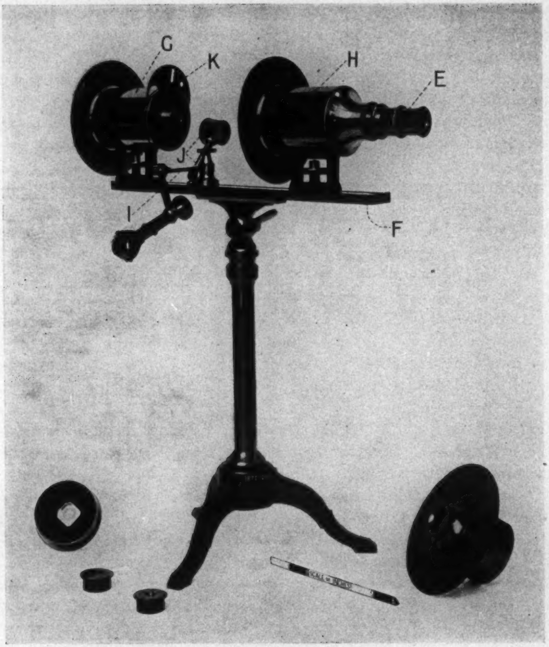

Fig. 6. Duboscq projection polariscope.

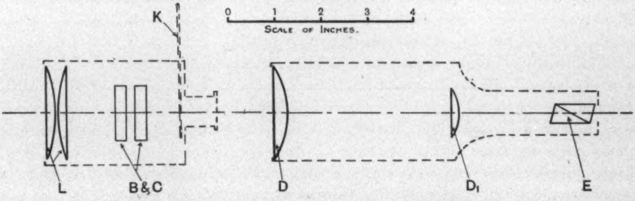

Fig. 7. Optical system of polariscope (by Ladd).

For projection in a convergent beam the object is held in the forceps referred to above and a condensing lens *J* is interposed between the object and the plate *K*, the projection being then effected by the lens *D*.

Fig. 8 shows a very simple form of petrological microscope as made by Fuess. The base *A* of the instrument carries a mirror *B*, and a pillar *C* and clamping screw to secure the upper part of the microscope. A sub-stage condenser, of the two-lens Abbe type, is combined in a tube with a nicol polariser. This tube engages with a sleeve, and can be set in azimuth in any one of three positions separated by 45°. The rotating stage is graduated in 5° steps. The microscope tube, which slides in a sleeve *D*, is fitted with an objective and crosswire eyepiece in the usual way. The analyser is mounted to rotate in a short sleeve carried by a hinged arm so that it can be thrown into and out of position.

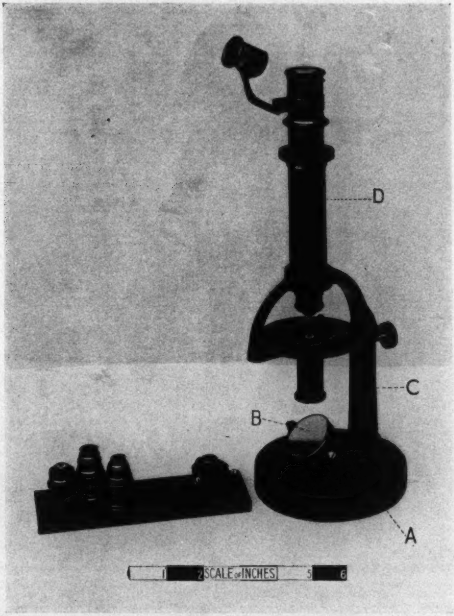

Fig. 8. Simple petrological microscope by Fuess.

Fig. 9 shows a form of petrological microscope, made by Nachet of Paris, in which the difficulties of centering are got rid of by mounting the object stage and the objective carrier to rotate together. The objective carrier *A* is raised and lowered by a rack and pinion *B*, carried by a pillar *D*, secured at the bottom to a lateral extension of the rotating stage. The separate upper end of the microscope tube, carrying the usual cross-wire eyepiece, is mounted to slide in a fixed sleeve, carried by an arm *E*. The nicol analyser is mounted in a separate cap, which may be placed over the eyepiece. The sub-stage condenser consists of a single small high-power lens combined with the usual nicol polariser, and adapted to slide in a sleeve carried by a swinging arm.

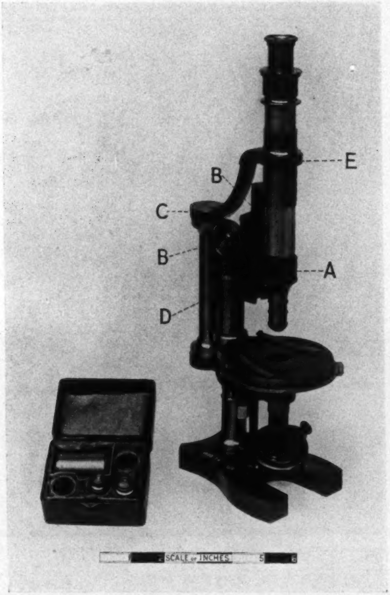

Fig. 9. Petrological microscope—Nachet type.

Fig. 10 shows a petrological microscope of the famous Dick pattern, invented in 1888, and made by Swift of London. In the ordinary type of microscope the object is carried by a rotating stage fitted with centering screws. In the Dick pattern, however, the stage is fixed and the polariser and analyser are so connected by gearing that they can be rotated together about the axis of the microscope. In the figure the analyser *A*, which can be adjusted independently in the usual way, is hinged to a tube *B*, to the lower end of which a spur wheel *C* is attached. This spur wheel engages with a pinion *D*, mounted on the upper end of a length of pinion wire *E*, which engages with a sheath *F* so as to rotate it, and at the same time leave it perfectly free to move longitudinally with respect to the pinion wire. The lower end of the sheath *F*, carries a pinion *G*, similar to *D*, which engages with a spur wheel *H* similar to *C*. The sleeve for the polariser, and it may be a divided circle, are fixed to the wheel *H*. Both the polariser and the analyser are capable of independent adjustment in the usual way, but by operation of the head *J*, fixed on the axis of the pinion wire *E*, the analyser *A*, eyepiece, and polariser can be rotated simultaneously, and at the same rate in the same direction.

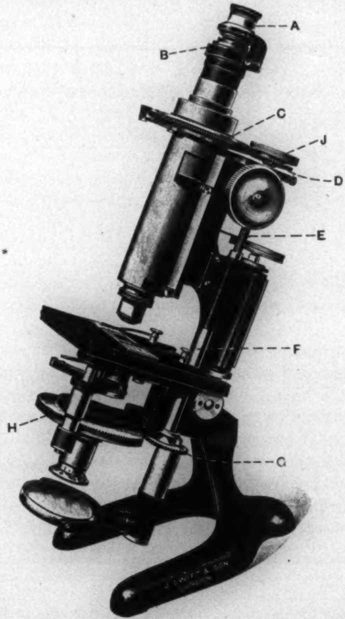

Fig. 10. A modern petrological microscope—Dick type.

MOTOR HEADLIGHTS

AT a meeting of the Society held on 11th May, 1922, the following papers, dealing with some of the optical and physiological problems connected with the design and use of motor headlights, were read, and a number of the headlights and devices described were exhibited.

GLARE FROM MOTOR HEADLIGHTS

BY JOHN W. T. WALSH, M.A., M.SC., F.INST.P.
(Photometry Department, National Physical Laboratory.)

THIS subject is one which has increasingly engaged the attention of all those who use the road at night ever since the introduction of powerful driving lights on automobiles. It formed the subject of a paper by Dr Hickman before the Illuminating Engineering Society of London in 1911*, and it has been the subject of lengthened investigation by a special committee of the Illuminating Engineering Society of New York ever since 1916. Their report of 1918† gives a very full description of the various problems underlying the subject and the last report of 1920‡ gives a revised specification which they recommend should be adopted in State Legislature and which has been so adopted in some States, including the State of New York. Before the war the matter was engaging the attention of the Local Government Board, for whom a lengthy series of experiments was carried out by the National Physical Laboratory in the years 1912–1913. During the war, with its restrictions upon the use of lights of all kinds, the problem did not arise, but it is now becoming more important than ever, and the increase in the number of accidents attributed to this cause shows that the matter calls urgently for attention. That this has been realised by the authorities responsible in this matter is shown by the appointment of a Departmental Committee of the Ministry of Transport, which has now produced three Reports on the whole subject§.

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* *Illum. Eng.* (*Lond.*) 4 (1911), 687.
† *Trans. Illum. Eng. Soc. N.Y.* 13 (1918), 259.
‡ *Ibid.* 15 (1920), 284.
§ First and Second Reports, Cd 659 of 1920; Third Report, 1921.

(1) *Headlight Requirements for Driving Purposes.*

The necessity for a powerful headlight on an automobile arises from the necessity for seeing objects or irregularities in the roadway (especially on the near side) at as great a distance as possible.

Now, although the sensitivity of the eye to contrast is approximately constant over a wide range (Fechner's Law), when the brightness is reduced below a certain limit the contrast sensibility is also seriously reduced. Fig. 1, due to König*, shows the relative contrast sensibilities (percentage difference of brightness just perceptible to the average eye) at various absolute values of brightness. For the sake of convenience in plotting, the field brightness is shown to a logarithmic scale. It will be seen that below a brightness limit of about 0·01 candle per square foot the contrast sensibility diminishes very rapidly so that this must be regarded as the lowest allowable brightness of the object to be distinguished. For an inconspicuously dressed pedestrian, whose clothes may have a reflection ratio of 10 per cent. (a maximum figure) this necessitates an illumination of 0·3 foot-candle which, at a distance of 100 feet from a headlight, calls for an effective candle power in the beam of 3000 candles. Such a candle power can only be obtained by means of a mirror behind a source of light of high brilliancy, such as a gas-filled lamp.

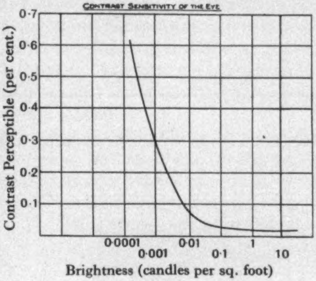

Fig. 1

Further, it follows that in order to obtain the necessary candle power with two headlights of 9 inches diameter (total luminous surface 1 square foot) the brightness of these must be at least 3000 candles per square foot. This brightness is about the same as that of white paper illuminated by direct sunlight and is at least 3000 times that of a newspaper illuminated for comfortable reading by artificial light. It follows that, if directly seen by an observer, such headlights are bound to produce the uncomfortable sensation known as glare.

(2) *Causes of Glare.*

It has been pointed out by Cobb† that the discomfort and disturbance to vision caused by what is generally known as glare is not *necessarily* related to an actual impairment of vision, but it is, nevertheless, well established that the ability of the eye to discern detail in any object is much reduced if the object is viewed when in the neighbourhood of a very much brighter object (glare by simultaneous contrast), or immediately after looking at a much brighter object (glare by successive contrast). This reduction is greater (*a*) the greater the brightness ratio between the two objects, and (*b*) the less their angular separation. Nutting* has found that the lowest brightness which the eye is capable of perceiving when viewed simultaneously with a glare spot having a brightness of about 1·7 candles per square foot varies with the angular distance of the glare spot as shown in Fig. 2.

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* König and Brodhun, *Sitzb. K. Acad. Wiss.* Berlin, 1888 (2), p. 917 and 1889 (2), p. 641.

† P. W. Cobb, *Amer. Journ. Physiol.* 29 (1911), 97.

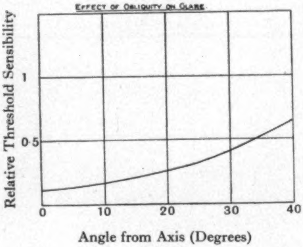

Fig. 2

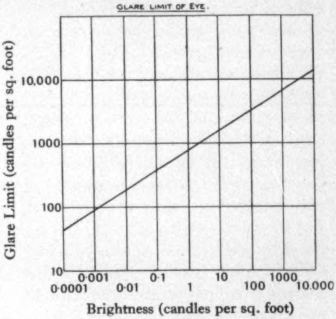

Fig. 3

In the curve of Fig. 3 each ordinate gives the brightness which is just uncomfortable to an eye adapted to the field brightness shown (to a log scale) by the corresponding abscissa. It will be seen from this curve that for a brightness of 0·01 candle per square foot this glare limit is about 180 candles per square foot, and if it be assumed that impairment of vision begins at three times this value it follows that the effective candle power of the headlights already mentioned must not exceed 500 candles.

This brings out very clearly the mutually antagonistic requirements of a headlight which is to be efficient for driving purposes, and one in which glare is to be avoided, and there seems to be no really satisfactory method of escape from this position of contradictory demands.

(3) *The Restricted Beam Method.*

It is clear that the insertion in the path of the beam of a diffusing glass, or any other device for reducing the general brightness of the headlight can only have the effect of lowering the effective candle power and producing an unsatisfactory compromise which is neither free from objection on the score of glare, nor satisfactory for driving purposes. The only devices which need be considered are, then, those which aim at *redistributing* the light in the beam so that while the necessary candle power for driving purposes is retained in the lower part of the beam, the upper part is either eliminated altogether or so reduced that it does not dazzle the eyes of anyone approaching the car on the off side of the road at a height of 5 feet or more above the ground.

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* P. G. Nutting, *Trans. Illum. Eng. Soc. N.Y.* 11 (1916), 939.

This method of overcoming the difficulty has been adopted by the Illuminating Engineering Society of New York, who, in their recommendations for the requirements with which headlights should be forced to comply*, suggest that it should be required that the (two) headlights of any car should together give a horizontal candle power of at least 7200 candles as measured at a distance of 100 feet from the front of the car. At heights of 5 feet and over above the roadway, 100 feet from the car, the effective combined candle power must not exceed 2400 candles. These measurements are made in the right ahead direction. At a height of 5 feet or over, when 100 feet away from the car, and 7 feet or more to the left† of the right ahead direction, the candle power must not exceed 800 candles.

The American requirements are, in brief, that the illumination of a vertical surface at a distance of 100 feet must be rather more than double the minimum mentioned in Section (1) above, so that the glare limit of 500 candles laid down in Section (2) is raised 50 per cent. and the candle power must not exceed this limit at a point which is likely to be the position of a driver of an opposing vehicle at a distance of 100 feet.

The British Committee of the Ministry of Transport make less definite recommendations of a somewhat similar nature. They say:

"(1) There should be a main beam of light having:
  (*a*) a minimum range of forward illumination of 150 feet and a maximum of 300 feet;
  (*b*) a minimum width of 30 feet with a maximum height of 4 feet from the ground at 150 feet from the lamp;
  (*c*) the lower edge impinging upon the road at not more than 50 feet from the face of the headlight;
  (*d*) the field free from dark patches and the illumination reasonably uniform or having good gradation.
(2) In addition to the main beam there should be a field of diffused light with a range of forward illumination not exceeding 50 feet, or less than 25 feet, with a lateral divergence at the road surface of at least 20 feet at a distance of 5 feet forward from the face of the lamp."

The "range" of the beam and its "width" are defined by the visibility or non-visibility of a standard disc, shown in Fig. 4, when illuminated in a certain specified manner‡.

(4) *Existing Devices.*

The number of devices which are on the market, or have been proposed, with the object of giving the beam the required distribution are exceedingly numerous, some two thousand having been already produced over five years ago§. The problem may, nevertheless, be regarded as still awaiting solution, for unfortunately the remarks made by the American Committee in 1918 remain true today. They say:

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* *Trans. Illum. Eng. Soc. N.Y.* 17 (1922), 103.

† With a right hand rule of the road (U.S.A.).

‡ *British Standard Specification for Disc for Determining the Illuminating Effect of Automobile Driving Lamps*, B.E.S.A. publication No. 151, 1921.

§ S. C. Rogers, *Trans. Illum. Eng. Soc. N.Y.* 12 (1917), 158.

"In conjunction with a simple paraboloidal mirror a great many forms of specially designed front glasses provide a wide variety of distributions of beam illumination. The front glass is the favorite device because of its simplicity, effectiveness and ease of operation....

Many of those on the market are more ornamental than useful and some, all things considered, are not as good as plain fronts. Good results may be secured with merely prismatic departures from parallel surfaces. Such front glasses do not produce secondary images outside the glass, which, being approximately as bright as the source itself, may give bad glare to passers. Spherical or cylindrical surfaces of short radius are to be condemned in that they are all wasteful of the light in the beam and that they form intense secondary sources, producing objectionable glare at considerable angles from the axis....

...It is found that fully half the trouble from defective lighting could be obviated by the proper adjustment of the devices actually in use. It is not uncommon to see headlamps directed upward so that none of the light reaches the road and all of it would produce bad glare to a passing driver. Probably not one lamp in ten is properly focused. A campaign for special devices should be preceded by a campaign for proper adjustment."

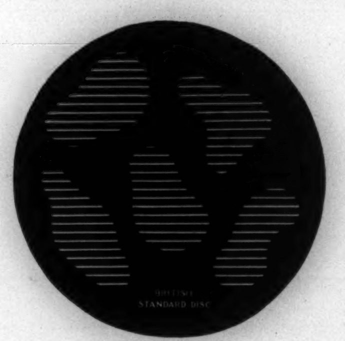

Fig. 4

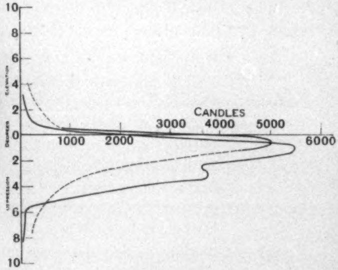

Fig. 5

Of the promising devices which have so far been produced probably that consisting of a series of prismatic elements in the front glass is the simplest. Fig. 5 shows a curve of light distribution obtained with such a device, the abscissae being the effective candle powers of the light at the angles of the elevation or depression shown by the scale of ordinates. The ideal requirements mentioned later in this paper [Section (5)] are shown by the broken line.

Other devices which have met with varying measures of success are:

(*a*) Various forms of split mirrors in which the top half of the mirror is so arranged that the lamp filament is in front of its focus, while for the bottom half the filament is behind the focus. It follows that the light from both halves then goes into the lower part of the beam. This type requires a very concentrated light source very accurately adjusted if the horizontal cut-off is to be effective.

(*b*) Various forms of lamp caps have been designed to reflect the light, which would normally go into the top half of the beam, into the lower half.

(*c*) Various forms of optical trains of mirrors and lenses designed to produce a beam of ideal distribution. These can be made exceedingly good in distribution and with a very sharp cut-off, but their overall efficiency as regards the light emitted is generally very low, and they are frequently bulky and heavy in design.

There are certain practical difficulties met with in all the devices which depend upon optical methods for their light distribution in the beam. These are (*a*) the limit of minimum divergence of the beam and its unevenness in intensity due to inaccuracy of the form of the mirrors or lenses used, and (*b*) the size of the source of light and the practical impossibility of manufacturing electric lamps so accurate in the form of the filament and its position in relation to the bulb and cap that one lamp may be replaced by another without altering the form of the beam. Ghost images of the filament in the bulb are frequently a source of trouble.

(5) *Practical Limitations.*

In order to obtain some idea of the limitations imposed by practical considerations it will be desirable to make certain assumptions as to the *ideal* (not *minimum*) requirements for a headlight which is to provide a good driving light without glare. These are:

(*a*) Maximum illumination to be at road level 100 yards ahead of the car, i.e. in a direction approximately ½° below the horizontal with a mounting height for the lamps of 2 feet 6 inches.

(*b*) No glare at a height of 5 feet above the road 100 yards ahead of the car, i.e. in a direction approximately ½° above the horizontal.

These requirements involve a reduction of the effective candle power of the beam from 5000 to 800 candles in an angular space of not more than 1°. To achieve this, the distance between the point of maximum brightness of the source and the point of negligible brightness must not be more than $f/57$ where f is the focal length of the mirror. The value of f is generally of the order of 50–70 mm. so that the distance above mentioned is about 1 mm. with a perfect optical system. Further, the position of the cut-off line must not vary by more than ¼°, i.e. the source must be constant in position to at least ¼ mm. unless the whole headlight is adjustable in position. The latter course is objectionable in practice as there are obvious difficulties in allowing the very fine adjustment involved to be altered at will by anyone who fancies that the position of the lamps is not correct.

It will be apparent that these requirements are exceedingly severe and perhaps impossible of attainment. They are stated here simply to indicate what is being aimed at and in order to illustrate the stringency of the practical requirements.

(6) *The Difficulties of the Restricted Beam Method.*

In addition to these practical difficulties of design there are certain difficulties inherent in the method of overcoming dazzle by restricting the beam to the region below the horizontal. These are quite outside the control of the designer and the most insuperable is that presented by a road which is not flat, or sloping in a straight line, but is convex or concave as regards its length. In the former case (e.g. the brow of an elevation) a car rising on one side must inevitably cast its main beam upwards and dazzle anyone approaching from the other side. In the second case, the beam is, in effect, depressed to a greater or less extent, and will cease to illuminate objects sufficiently far ahead of the car. A similar difficulty is that presented by inequalities of loading of the car. Too much back load will tilt the beam upwards and cause glare, while too little back load will produce the same effect as a concave slope.

Another drawback to the use of a beam which is almost entirely below the horizontal is its inability to show signposts, overhanging branches of trees, and other objects above the 5 feet level which it is important for the motorist to be able to recognise quickly. If this objection be overcome by confining the non-glare region to the off-side of the road (a system generally referred to as the "three-quarter beam") it is obvious that glare will not be avoided when turning corners, a position in which maximum ease of visibility is generally desirable.

(7) *Conditions of use and Legislative Enactments.*

Although not strictly part of the optical problem, it is clear that the conditions under which automobile headlamps are installed and maintained cannot be ignored when design is being considered. The most perfectly designed and constructed headlamp is worse than useless if not properly understood and intelligently used. Any considerable degree of fool-proofness is probably impossible in the case of a non-dazzle headlight. The American recommendations provide for a laboratory test of headlamps, but this is very far from ensuring their correct use.

Still more difficult is the framing of legislative enactments which can be enforced under conditions of use and practically without any testing apparatus. This is clearly realised by the Committee of the Ministry of Transport who in their third report say:

> "The Committee recognise that the enforcement by the police of regulations upon the lines recommended may present considerable difficulties in practice, and that general compliance therewith can best be attained by coöperation between the lamp manufacturers and the owners of mechanically-propelled vehicles, who, it is hoped, will realise that the regulations are in the interests of the public using the highways. If such coöperation is attained, the Committee do not anticipate that action by the police would be necessary, save in very rare and exceptional cases."

Nevertheless it is imperative that some action should be taken to enforce compliance with reasonable minimum requirements, and there is no doubt that the simpler the apparatus necessary in order to give a satisfactory result, the more easy the establishment and enforcement of legislation in this direction. At the present time thirty-five States in America have legislation demanding a minimum candle power of beam in the forward direction, while fifteen place an upper limit on the candle power above the horizontal*. In addition nineteen States specify a maximum candle power for the lamp used inside the projector. It is clearly most desirable that legislation of this kind should be as uniform as possible not only in one country but throughout the world, and the International Commission on Illumination at its Paris Session last year established a special Committee charged with the duty of endeavouring to secure as much uniformity as possible in this direction.

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* *Gen. Elect. Rev.* 25 (1922), 120.

This paper is intended to serve merely as a brief *résumé* of work already done on the subject, and a short bibliography is therefore appended.

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THE C.A.V. (GRUBB'S PATENT) NON-DAZZLE HEADLIGHT

By Sir HOWARD GRUBB, F.R.S.

The problem of designing the best form of non-dazzle headlight for motor cars appears at first sight a simple one, viz. the production of an optical train of lenses or mirrors or combination of both which will collect the largest possible amount of light from the illuminant, be it an electric bulb or otherwise, and project the greatest possible percentage of that light on certain portions only of the road or landscape, the border line or demarcation between light and dark portions being reasonably sharp and well defined even at considerable distances.

In the early stages of the investigation it was assumed that if all light could be blotted out which would be projected over a certain datum line, say 1 metre from the ground and that this could be done with a fairly sharp line of demarcation between light and darkness, even at 100–200 feet, the problem would be solved.

This result can of course be obtained by treating a lamp with a condenser of either a catoptric or dioptric form as an illuminated object, and placing a lens in front to project the image of that illuminated object on the distant landscape; that image will of course be of the same form as that of the illuminated object inverted, and if this be, say, a semi-circle and its straight edge horizontal as in Diagram A, the image projected will be as in Diagram B, Fig. 1. It was found, however, that this was very ineffective and gave (among other disadvantages) entirely too much light on the road and near the car and insufficient light where it was most wanted, namely on the more distant objects on the road.

Various experts were consulted as to the best distribution of light with the result that the problem was found to be not nearly as simple as was at first assumed, the greatest difficulties arising from the fact that there was found to be an enormous difference of opinion as to what was really wanted. Not only were different conditions demanded by different countries, but in some countries, such as the United States of America, the regulations varied in different States, while even in Great Britain the various authorities consulted were found to have widely different ideas as to what was required. Some insisted that the road in front of the car should be brightly illuminated, sufficient to see the smallest animals passing across, some considered that this illumination of the near portion of the road interfered with the visibility of the more important distant objects, some insisted on a wide beam of light, and others wanted it all concentrated in something like a spot light. Others considered that it was necessary to have sufficient light projected above the datum line to render larger objects, such as trunks of trees carried on an approaching lorry, visible to the driver of the motor car, ignoring the fact that any light sufficient for this purpose would effectually dazzle the driver of an oncoming vehicle or others in the neighbourhood. This diversity of opinion as to what was really desirable necessitated a long series of experiments culminating in the lamp to be described.

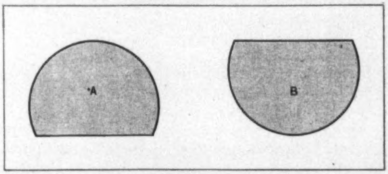


Fig. 1.

It is not claimed that this lamp fulfils all the conditions asked for by various authorities. In fact this would be impossible; but it will, I believe, be found to be efficient from the point of view of the driver of the motor car carrying it, and will provide comparative safety to the man in the street and the driver of any oncoming car or vehicle. The general construction of the lamp is as shown in Fig. 2. A paraboloidal or, preferably, ellipsoidal mirror is used to collect the light from the bulb and project it forwards in a slightly converging beam. Immediately in front of the mirror is a diaphragm with openings *A*, *B*, and *C*; some 10 inches in front of this diaphragm is a compound moulded lens which from its construction is really a combination of 10 separate lenses arranged in three tiers or storeys, each storey opposite one of the three apertures of the diaphragm. The upper storey forms four images of the upper opening in the diaphragm on the distant object, all superimposed on one another. The four lenses in the middle storey project four images of the centre aperture, superimposed on each other and on the four images of the upper aperture; and the lower two lenses form two images of the lowest aperture in the diaphragm, again superimposed on the others. Thus there are in that part of the field which is required to be brightest 10 overlapping images, the upper boundary lines of which coincide with one another. In order to obtain this result, the optical centres of the whole 10 sections of lenses must be in the positions shown by the small circles. If it be desired (as is the case in one country) to project a small amount of light above the datum line, it is necessary so to form this moulded window as to shift the optical centres of one or more sections a little higher. In this way the projection of the light can be modified in any way required and a general light can be obtained by muffing a small ring at the outside of the lens.

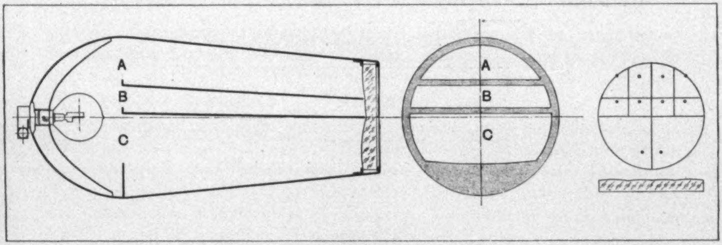


Fig. 2.

As regards the results obtained with this lamp and how far these results fulfil the requirements of various countries, no one arrangement of overlapping images will be found to give results that will meet the demands of all the different authorities, even when they make up their minds as to what they really want, but it will perhaps be best to take one example, preferably that of the United States, as the authorities there appear to have gone closely into this question, and whether they are right or wrong their regulations have assumed a concrete form. Unfortunately the various States are not "united" as to their regulations, but the lamp exhibited has been constructed with a view to meeting the requirements of the authorities in the State of Massachusetts, which appear to be the most stringent of all. The diagram shown in Fig. 3 gives these requirements and the following table shows the results obtained at a test made in April at the Electrical Testing Laboratory, New York. It should be observed that these figures were obtained with a standard

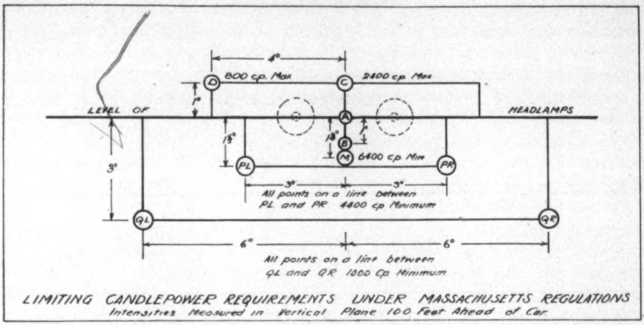

4°
D
800 cp. Max
C
2400 cp. Max
1°
LEVEL OF
A
HEADLAMPS
1½°
1½°
B
M
6400 cp Min
PL
PR
3°
3°
All points on a line between
PL and PR 4400 cp Minimum
QL
QR
6°
6°
All points on a line between
QL and QR 1000 Cp Minimum
LIMITING CANDLEPOWER REQUIREMENTS UNDER MASSACHUSETTS REGULATIONS
Intensities Measured in Vertical Plane 100 Feet Ahead of Car

Fig. 3.

American bulb of 21 candle power, this being the maximum allowable by the State of Massachusetts, the majority of the States allowing up to 32 candle power.

TABLE OF AMERICAN TESTS

Point	Required	Figures obtained under test
D	800 max.	800
C	2400 max. 800 min.	1480
A	6000 max. 1800 min.	6000
B	7200 min.	7800
PL	5000 min.	6400
PR	5000 min.	5100
QL	2000 min.	2600
QR	2000 min.	2600

As regards the general question of the importance of requiring motorists to use some efficient form of non-dazzle lamp much has been said and written. It may perhaps have been observed that nearly all that has been written upon this subject, more particularly in the daily papers, has been communicated by motorists and very little by other road users, who are probably the chief sufferers from this cause.

As long as non-dazzle lamps were deficient in illuminating properties, motorists could hardly have been expected to go to the expense of having these fitted to their cars, as they would naturally argue that the additional safety to the public from the adoption of the non-dazzle lamp was to some extent at least counter-balanced by the additional risk of carrying a less safe driving light. But now that non-dazzle lamps are available that give practically equal illumination to ordinary dazzle lamps in all areas that are necessary and fulfil such stringent regulations as those of the State of Massachusetts, there can be no valid objection to their adoption, and no doubt can exist as to the great increase to the public safety.

MOTOR HEADLAMPS

By HERBERT S. RYLAND.

In this paper the term "glare" is used to define that series of phenomena which, taken together, cause annoyance, and often danger, when meeting the average headlight on a dark road. The phenomena may be summarised as follows:

1. The "after image" effect. When the image of a bright object falls upon the retina, its extinction is followed by a "ghost" or "after image," which is usually coloured and persists for an appreciable time. Since the image of a headlight is usually in motion upon the retina, the after image takes the form of a band and obliterates, temporarily, the images of such other objects as are generally near a headlight.

2. The after image rapidly changes form. If the flint of a dry petrol lighter be struck in a dark room a number of brilliant streamers, quickly followed by an after image, will be seen. This after image will rapidly change form, generally contracting to a bright patch.

3. The image of a bright source falling suddenly upon the retina causes an involuntary movement of the eye with the object of bringing the image on to a fresh part of the retina. As a result the sense of direction is for a time lost. This phenomenon can easily be seen by experiment. In a dark room have some object of very small illumination in line with an electric lamp. If an assistant switches the light quickly on and off, a multiple after image will be seen.

4. When the image of a bright source falls upon the retina, that part of the retina surrounding the image in insensitive to light. The extent of this insensitive area, and the degree of insensitivity, would appear to depend upon

(*a*) the size of the source,

(*b*) its intensity,

(*c*) the sharpness of its boundary.

All of these phenomena appear to depend to a small degree upon the colour of the source.

"Glare" is a relative term. Ordinary side lamps, bicycle lamps, and street lamps cause little inconvenience to road users. On the other hand even a glowing cigarette will cause great inconvenience to a look-out man at sea on a dark night. Glare seems to depend very largely upon the size, or apparent size, of the source. It will be seen from the phenomena described that this size depends upon the extent of the disturbed visual field.

The usual type of electric headlamp consists of a parabolic reflector with the filament at its focus. The beam from this may be divided into two parts, a divergent cone of parallel pencils from the reflector, and a cone of "free" light diverging from the source through the aperture. To an observer in the main beam the full aperture of the reflector appears to be full of light of greater brightness than the source itself.

The images of a pair of 9-inch headlights 150 feet distant causes, in the author's case, a disturbed retinal area greater than the image of the full road width of 60 feet. These remarks apply to all headlamps having a source at the focal point of a lens or mirror.

The usual type of lamp suffers from the further defects that the light which does not go to form the effective beam is lost, the beam is seldom homogeneous, and stray light rises above the level of the driver's eyes, thus obscuring vision in fog or mist.

The ideal method of lighting would be to provide adequate and even road illumination. Failing this, in the author's opinion the following conditions should be fulfilled in the design of a headlamp:

1. The image of the source to be as small as possible.
2. The apparent brilliancy of the image to be as small as possible.
3. The direct light from the source to be kept approximately parallel with the road.
4. The beam to be homogeneous.
5. As much as possible of the light from the source to be within the beam.
6. The lamps should not require attention from the driver when passing other road users.

Any attempt to solve the problem by maintaining a level, or by modifying parts of the beam in particular directions, is nullified in practice by the movement of the car and by inequalities in road surface and loading.

The methods used to reduce glare at present are:

1. By diffusion either by frosted glass or a lens or prism system on the front glass.
2. By means of opaque or tinted shutters to stop or tint parts of the beam.
3. By prism system to depress the beam.
4. By subsidiary reflection to send parts of the light on to selected parts of the main reflector.
5. By passing a part of the light to the rear to illuminate part of the car body.
6. By lenses and mirrors either cylindrical or other than surfaces of revolution to modify the whole or part of the beam.
7. By dividing the beam into elements by plates fitted to the mirror or surrounding the bulb.
8. By diffusing or dimming.
9. By switching off the main lamp and turning on a lamp at right angles to the car's direction.

The author has designed and protected two headlamps in which an attempt has been made to fulfil anti-glare conditions. One consists of a spherical mirror *A* (Fig. 1) with the filament *B* at its centre of curvature. In front of the filament is a condenser *C*, beyond which is a projection lens *D* placed at its focal distance from *C*; the aperture of *D* is sufficient to receive the image of *B* formed by *C*. A mirror *E*, having the form of an ellipsoid of revolution, extends from *A* to the plane where it intersects the projection of *C* with *B* as origin. One of the foci of *E* is at *B* and the other at the centre of *D*. A prism *F*, or series of prisms, may be incorporated with *D* to depress the upper limit of the beam; also a cylindrical element may be used to make the beam of oval instead of circular form. Where it is desired to use a very narrow divergence, the projection lens *D* takes the form of a specially modified telephoto system.

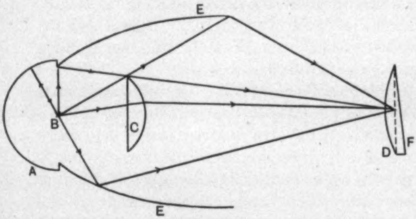


Fig. 1

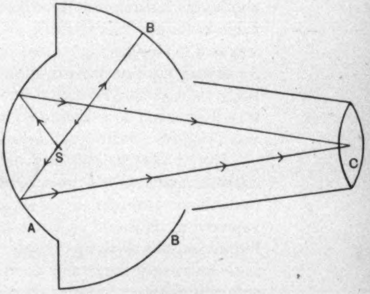


Fig. 2

The second lamp consists of a reflector *A* (Fig. 2), having the form of an ellipsoid of revolution, with the filament at one of its foci, *S*. Facing the ellipsoidal reflector is a hemispherical reflector *B*. The centre of *B*, the focus of *A*, and the edges of both *A* and *B* all lie in a plane perpendicular to the major axis of *A*. An aperture is cut in the vertex of *B* and a projection lens *C* is fitted by means of a short tubular extension.

It will be seen that all of the light from the filament in each case reaches the projection lens; also that there is no stray light. Finally, the aperture is small; in the examples exhibited it is 1·75 inches. Although both of these lamps give a full headlight beam, the glare is not more than that from an average side lamp. This has been verified by independent observation.

ON AUTOCAR HEADLIGHTS

By Fr. MEYER.
(Messrs Carl Zeiss, Jena.)

The question as to whether a motorist should be at liberty to use headlights liable to dazzle pedestrians or the occupants of vehicles travelling in the opposite direction has been discussed so often that it would almost seem superfluous to say any more about it. Yet, the views of the two parties concerned—the motorist and the public—are as divergent as those of landlords and tenants under the blessings of an act which under one form of illumination presents itself as rent restriction, under another as tenancy extension. The fact is, the motorist wants a light which will reach as far ahead as possible, so as to enable him to anticipate any obstacle in his way and to stop his high-speed car in good time, if necessary. Obviously, facilities for driving a car at night at speeds which are attainable in day time add very materially to its value. Many business men prefer the late hours of the evening for travelling, so as to keep the entire day free for business; and, naturally, an hour saved by fast travelling and secured for rest is not to be despised.

This, however, can only be achieved with bright and therefore somewhat dazzling headlights of the searchlight type. The public, on the other hand, looks upon these powerful flaring lights as a threat to its safety, and in a sense it is justified in so doing. It would be a monstrous affront to the chivalry of the road if in much frequented places every car were to light up its track with glaring headlights, the more so as very deplorable accidents have occurred from this very cause. In the majority of cases, however, the blame for the accident lies with the public. If, instead of turning their backs to the approaching car and stepping out of the beam of light in the brightly illuminated street or road, a pedestrian faces the car and its dazzling lights and then frantically leaps from one side to the other, he places the driver of the car in an almost hopeless position. Many accidents could have been avoided if pedestrians would remember that a motorist does not deliberately run over anyone who is steadily walking along the road and whom he can see. I do not suggest, of course, that the indiscriminate use of headlights is to be advocated, or that it is justifiable in inhabited localities. On the other hand it does no good to forbid altogether the use of bright headlights, even though they dazzle, as has been done in some countries. In some cases no headlights are permissible which throw a beam above a certain height, say 39 to 48 inches above the ground. This is a regulation which seriously cripples a projector as a means of lighting up a long way ahead. For, in every projector, no matter how well designed, the comparatively short focal length of its optical component inevitably gives rise to dispersion of the beam through several degrees in upward and downward directions. Dipping the headlight sufficiently to prevent the bright beam from rising more than 39 to 48 inches above the ground will cause its central shaft to meet the ground only a few yards in front of the car, where it lights up the ground in such an exaggerated manner as actually to interfere with the view farther ahead. With the beam thrown out in a horizontal direction any obstruction in the road can be seen at a distance of 150 to 200 yards on a dull, but adequately illuminated, track.

Complicated devices of the nature of prismatic front attachments, etc., which have been advertised by various British and American makers, do not overcome the evils of this restriction. In fact, if regulations of this kind should be persisted in, there would be no object in constructing any good and expensive brightly shining headlights, since any common lamp would be good enough for lighting up near objects. Under these conditions it becomes impossible to travel fast at night.

The following is a brief description of the headlights made at the Zeiss Works at Jena. These have a device by means of which the glare may be cut off by the driver and the light dimmed to the amount necessary for slow running. The driver should be under legal compulsion to cut off the full glare in lighted localities and when meeting vehicles carrying lights.

The design of the headlights should fulfil the following essential conditions:

They should be capable of throwing a beam of light a long way ahead on a country road. They should furnish an adequate illumination to either side for negotiating curves, and they should be provided with means for cutting off the glare at any time and instantaneously.

The intense light required for fast travelling on country roads is not attainable with the acetylene lamps fitted with lenses and sheet metal reflectors, as hitherto in use. It became necessary to employ lamps constructed on searchlight principles in such a way that the whole of the light furnished by the available source of light may be emitted by the optical component in the form of a beam of parallel rays. This secures the highest degree of intensity. It is not possible to attain this end with the aid of a combination of lenses, to say nothing of the large proportion of light which is absorbed by thick lenses. The desired result is best accomplished by the use of a parabolic reflector, thanks to the well-known property whereby it gathers all rays proceeding from a luminous point situated in its focal plane and sends them forth in the form of a beam of parallel rays of a diameter equal to that of the reflector. Now, all sources of light embrace a more or less extensive area—they are not points—so that every point constitutes a focus whence a parallel beam proceeds by reflection at the angle with respect to the optic axis at which the ray proceeding from the luminous point meets the apex of the reflector. Hence the larger the source of light and the shorter the focal length of the mirror, the greater will be the angle of the emitted outer beams of light with respect to the axis, that is, the greater will be the dispersion. Now, in order that the dispersion may be sufficient for taking curves, reflectors have been made with their focal lengths as short as possible. Also, to collect the utmost amount of light, reflectors have been given an extremely deep section. As a result the light is dispersed, not only to either side, where it is needed, but also in upward and downward directions, where it fulfils no purpose. Moreover, the light which emerges in front, without being reflected and collected by the mirror, is scattered in all directions.

Messrs Zeiss were the first to design projector lights in which these defects have been overcome, in the first place by giving the reflectors a much flatter profile and a longer focus. In these lamps the light, which in the older headlights shone directly forward, is rendered available for reflection by the parabolic mirror by placing a small spherical mirror in front. One of these earlier headlights is shown in Fig. 1.

Naturally, these reflectors furnish a far more intense light, since the whole of the light is collected and concentrated within a relatively small space. The beam which they form is therefore best adapted for lighting when travelling along a straight track at a maximum speed.

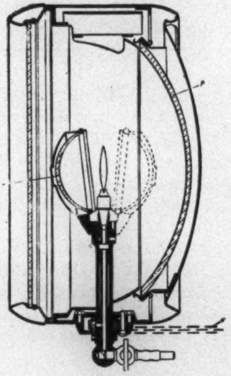


Fig. 1

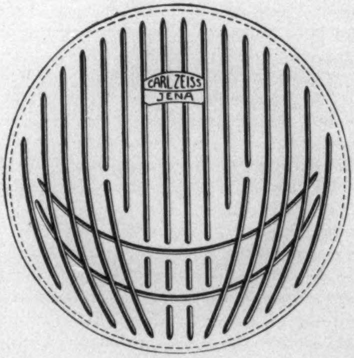


Fig. 2

A different arrangement was needed for the negotiation of curves. In this case a beam lighting up a long track would be most undesirable; moreover, the brightness in the curves may be much less than at the middle. The lamps were accordingly fitted with glass fronts provided with specially formed prismatic ribbing (Figs. 2, 3) by the action of which a small portion of the full light is deflected to the right or left as well as in a downward direction. The extent of this deflection is just sufficient to cover the curve and to provide the requisite amount of lighting in front. By this means the whole of the available light is accordingly collected and directed in appropriate quantity where it is required for taking the curve. No light is lost, and the intensity of the main body of the light is lessened by an inappreciable amount. The shallow form of the reflector has rendered it possible to make it of glass instead of sheet metal, as in the older headlights. The glass reflector has the advantage that it may be endowed with a much higher polish than is possible in the case of sheet metal mirrors. This in itself conduces to a greater intensity of the light.

The life of the silvering is almost unlimited, since the glass is silvered at the back. The coat of silver is further protected by a deposit of copper and an application of varnish.

The reason why glass reflectors are not used universally is to be found in the fact that they are far more difficult to make than other kinds of reflectors. Metal reflectors may be drawn, spun, or cast, whereas glass reflectors require to be sunk and then ground and polished according to optical standards. It is an easy matter to grind a spherical reflector, but it is a laborious business to achieve a good parabolic surface and, moreover, the difficulty increases with the depth of the mirror.

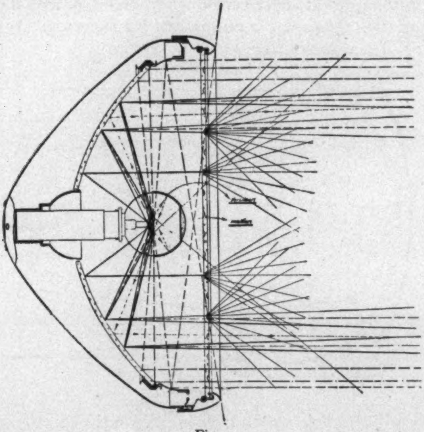


Fig. 3

Truly faultless mirrors of great depth are necessarily too costly for use in headlights. At the Zeiss works the angle of aperture of the reflectors is not allowed to exceed 180°, but within this limit the mirrors are sunk, ground, and polished to satisfy exacting optical requirements.

The extensive use of sheet metal reflectors, and even mirrors made of ceramic materials coated with silver foil, is only justified by the fact that they are much cheaper to produce. It cannot be denied that very excellent mirrors are made of sheet metal. Unfortunately, sheet metal reflectors have the disadvantage of being extremely sensitive, so much so that they may barely be touched without an immediate risk of nasty patches forming on their surface; these cannot be removed, for the mirrors may not be cleaned with a polishing cloth, since the silvering, just like the silver foil, requires to be protected from oxidation by a coating of colourless lacquer. Despite this protective coating the reflecting capacity of these mirrors declines very soon.

Mirrors silvered in front have undoubtedly a very high reflecting capacity, but this lasts for a short time only. In many cases the reflectors are permanently attached to the glass front for the better protection of the silvering. The chauffeur has then no access to the reflecting surface. In the event of the glass front being shattered, which happens often enough, the mirror would more likely than not be destroyed as well.

Fig. 1 shows a Zeiss acetylene headlight. The flame is at the principal focus of the large parabolic reflector and at the centre of the spherical mirror. Fig. 4 shows the path of the rays within the reflector. The dimming effect is obtained by turning the small spherical mirror through an angle of 180° about the axis of the flame. This cuts the light off from the parabolic mirror, and the flame together with the small spherical mirror will now light up the track in front of the car (Fig. 5). Headlights of this type have been made by Messrs Zeiss for the last twelve years.

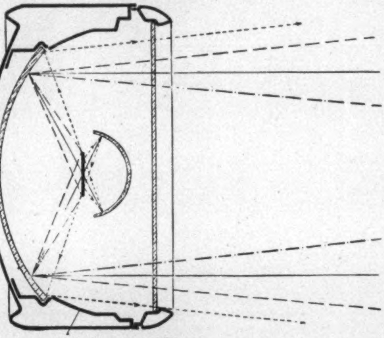


Fig. 4

Fig. 6 shows a Zeiss electric headlight. It will be seen that the mirror encloses one half of the incandescent lamp bulb. The light which in the ordinary course would pass out in front is intercepted by the silvered front half of the bulb. The latter throws back the whole of this light, as in the case of the acetylene lamp, upon the parabolic reflector, so that the whole of the light furnished by the incandescent lamp is turned to account. The central portion of the bulb corresponding to the size of the lamp fitting is left unsilvered and is frosted, so that the light which otherwise would be idly reflected back upon the fitting may emerge in front and is thus rendered available for lighting up the track.

An important feature of the Zeiss headlights consists in the focussing arrangement to the incandescent lamp. Unfortunately these lamps, as supplied by their makers, are not always sufficiently uniform to ensure a complete use of light under all circumstances. It was therefore found desirable to provide the lamp with a focussing adjustment.

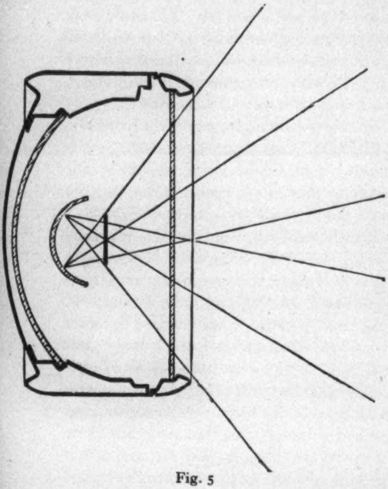


Fig. 5

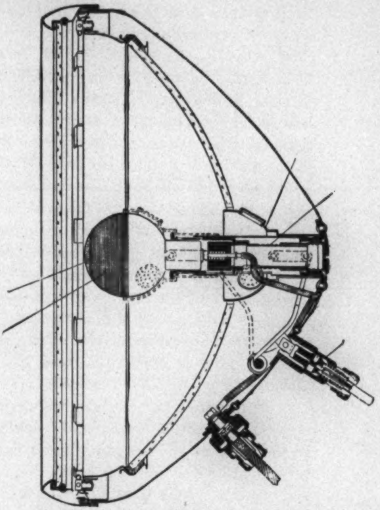


Fig. 6

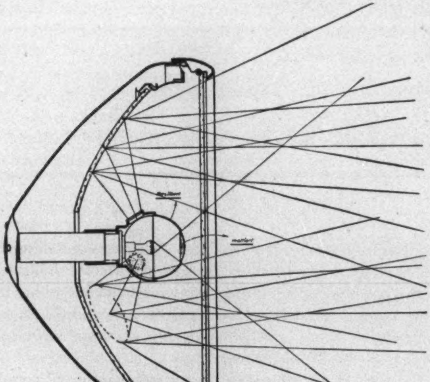


Fig. 7

In the new Zeiss headlights dimming is effected, through the agency of a Bowden wire, by pushing a hemispherical cup of sheet metal from the back over the bulb, whereby the light is cut off from the reflector. In order that there may be sufficient light for driving through towns, the cup is fitted with three small densely frosted glass windows (Fig. 7). If sufficiently opalised, these windows behave like self-luminous sources of light. There is therefore no glaring effect, since the windows are not in the focal plane of the mirror. In fact, the effect produced within the headlight is that of three greatly magnified images of the windows, which adequately light up the track without producing any glare whatever. Nevertheless, the light thrown on the track is much brighter than that obtainable by the use of a small lamp at the side or in the upper part of the headlight, in that the presence of the three small windows ensures three times the amount of light.

The consumption of current is naturally the same in dimmed and in undimmed headlights, which is frequently regarded as an objectionable anomaly. The answer to this objection is that it is quite immaterial, so long as the dynamo is running, as to whether a little more or less current is absorbed. It is only with the dynamo out of action, when stopping in the road, that the larger amount of current used becomes a matter to be considered, since it involves a heavier strain upon the battery. But even then there is, generally speaking, no actual loss, since car batteries are notoriously far more often damaged by overcharging than by being allowed to run down. In the majority of cases motorists do not completely discharge their batteries, and yet it is absolutely essential for the welfare of the battery that this should be done periodically. Those, however, who insist on economising battery current are at liberty to light their cars during waiting periods, with the motor standing, by means of two very small lamps of the type of number plate lamps at the sides of the mud guards, switched on in place of the headlights. As stationary lights these lamps fully satisfy all existing regulations.

TWO IMPROVED MOTOR HEADLAMPS

By E. CULVER.

(The United Kingdom Optical Co., Ltd.)

The first lamp has been designed to enable a driver to see well ahead and yet not to inconvenience others. Almost all of the light is collected and projected straight ahead, or, by the use of modified fronts, part or all can be spread out sideways if desired. In the lamp exhibited part of the light is spread sideways to illuminate the width of the road without causing dazzle, whilst a very bright light is projected forward with a small dispersion sideways.

This is effected by the combination, in a novel manner, of certain well-known optical parts, viz.:

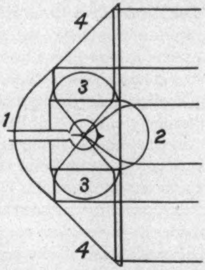
(1) a spherical reflector,

(2) an improved condenser or bull's eye lens,

(3) an improved dioptric ring,

(4) a conical reflector,

arranged so that almost all the light from the source is collected and projected forward nearly parallel or with just such dispersion as is desired. The four parts mentioned are used as shown in the diagrammatical sketch.



(1) *The Spherical Reflector*, which can be either polished metal or silvered glass, has a radius of curvature equal to its distance from the source of light and such a diameter that it collects a cone of rays equal in angle to that collected by the front lens.

(2) *Improved Condenser or Bull's Eye Lens*. This being corrected for spherical aberration can be used to collect a cone of rays of much wider angle than usual for projection.

Thus all the rays which are reflected from the back reflector together with those falling directly on the front condensing lens are projected forward as a very narrow beam, the height of which can be controlled independently; the beam may be widened out to any desired amount by making the inner surface cylindrical without any further divergence up or down.

(3) *Improved Dioptric Ring*. The remainder of the light is collected by a ring lens having its focus at the centre of the ring. This ring has its outer surface of toric form and the inner surface cylindrical, its cross section being the same in form as that of the front condensing lens. It is spherically corrected, so that rays collected over a large angle are projected quite parallel. For the purpose of making the ring lighter it can be made in the form of a dioptric ring as used in ships' lamps, but this is not a great advantage.

(4) *Conical Reflector*. This is in the form of a hollow cone, whose sides make an angle of 90° with each other, so that the parallel light falling on it through the ring lens is projected forward as a small annular beam of light when the source is very small, but as a narrow beam from an ordinary small electric bulb.

The front lens is carried in a fluted glass circle, which acts as a number of cylindrical lenses and diverges the light collected by the dioptric ring sideways.

The second lamp produces the same beam as the first, but the light, instead of being collected by a toric ring, falls upon a parabolic reflector. The lamp, therefore, consists of a spherical reflector, almost hemispherical, and a parabolic reflector with the same front lens arrangement as in the first lamp. The electric bulb is carried in a vertical position and can be adjusted in any direction to get correct focus. The condenser lens, being placed above the centre of the front glass, brings the beam from the condenser to the top or above the top of the other beam, enabling the lamp to be inclined downwards, thus throwing only a very narrow accurately defined beam horizontally.

HALL'S PATENT "PARALENS" ANTI-DAZZLE MOTOR LAMP

By JOHN I. HALL.

The Paralens is a device which, when substituted for the ordinary glass in a standard pattern motor headlight, eliminates glare and dazzle. It forms a sectional part of a plano-spherical lens or of other lenses which give the same result in working. It is obtained, geometrically, by taking the vertical radius above the horizontal diameter of a plano-spherical lens as its diameter. The optical axis of the Paralens is on the periphery, and rays of light after converging to its focus diverge below the optical axis only, no rays being projected above. Hence with parallel incident light on the back of the Paralens no light is projected upwards and there can therefore be no dazzle produced.

In order to increase the intensity of the upper part of the beam the Paralens is made up of sections, each of which gives a shallow beam of light parallel to the geometrical axis of the lamp. The number of sections obtainable is limited by the diameter of the lens and practical considerations of construction. The beam from such a sectionally constructed lens is rectangular in cross-section.

The Paralens can be made to give any desired horizontal divergence. The simple lenses give a divergence of 5 degrees, but for motor cars sectional lenses are needed, as they give a beam complying with the requirements of the Ministry of Transport, who suggest a beam 60 feet wide 300 feet in front of the car.

With regard to the illumination of the roadway, Mr Lock of Messrs Smith & Sons, Cricklewood Works, very kindly carried out some photometrical tests on sectional lenses. The first test was with a lens consisting of five sections, the horizontal divergence of which is 11·5 degrees and the vertical divergence 2·3 degrees. At 300 feet ahead of the car the beam is 60 feet wide. The particulars of the test are: diameter of lens, 5·5 ins.; height of lamp from ground, 3 ft.; distance ahead at which measurements were made, 214 ft. About 2 ft. above ground level the illumination extended evenly across the beam for 25 ft. The illumination, as measured by the photometer, was 0·075 foot-candle.

The second test was with a facet covered lens in a lamp made by Messrs A. H. Hunt, Ltd., of Croydon. The horizontal divergence is 10 degrees and the vertical divergence 5 degrees. The lens gives 11 partial beams, the total beam being 52 ft. wide 300 ft. ahead. The horizontal illumination was uniform over a width of approximately 30 ft., or nearly the whole width of the beam 214 ft. ahead. The illumination was 0·06 foot-candle.

Two lamps, therefore, would give 214 ft. ahead an illumination of 0·15 foot-candles in the first case and 0·12 foot-candles in the second case. By way of comparison it may be mentioned that the illumination in Oxford Street mid-way between lamps is 0·02 foot-candles. Thus two Paralens lamps give, at a distance of 214 ft. ahead, approximately seven times the minimum illumination provided in Oxford Street.

In conclusion, I would say that, although diminishing dazzle, the lenses tried so far do not eliminate it altogether. This is due to the large dimensions of the source of light compared with those of the reflector, and to the aberration of the beam; aberration causes loss of efficiency in ground illumination.

I have found that it is quite possible to eliminate dazzle if moderate candle power is used, but with the large candle power electric lamps used by some motorists a certain amount of glare will occur, although not sufficient to cause unpleasantness.

By means of the semicircular construction used inside the lamp no rays from the source of light are emitted above the horizontal diameter of the lamp. Thus in misty or foggy weather observation is not restricted by illumination of the mist or fog above the lamp.

Note added later. Since the meeting on 11th May Messrs Siemens Bros. & Co., Ltd., have made some special electric lamps for me, of a type not previously employed in motor headlights. They provide a close approach to point sources. In combination with a Paralens headlight this type of lamp is very effective; the vertical aberration of the beam is so much reduced that the intensity of the beam is increased by approximately 30 per cent., and dazzle above the top of the beam is entirely eliminated.

ANTI-DAZZLE LENS FOR MOTOR CAR LAMPS*

By C. G. SMITH, A.M.I.E.E.

THE purpose governing the design of the usual type of motor lamps is to project rays of light of fairly high illuminating intensity to a sufficient distance in front of the car to enable the driver to see and have time to avoid any obstruction or danger. In presenting his own design of a lens for the purpose, the writer's contention is that apart from the objectionable dazzling nature of the light projected by the lamps in question its quality as an efficient illuminant is by no means beyond criticism. The very intensity of concentration required under ordinary conditions, to project a beam of light the required distance, militates against the diffusion necessary for effective illuminating purposes, and as a consequence a very disagreeable and confusing effect of high lights and deep shadows is produced.

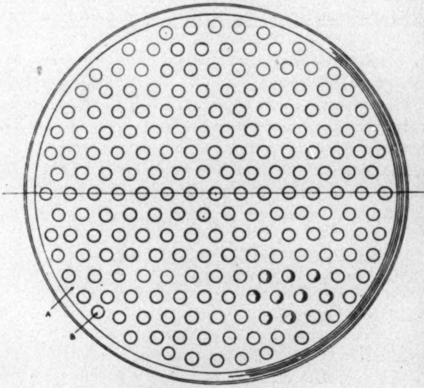
In the course of his experiments the writer has found that by interposing in the path of the beam, near its source, a screen consisting of a number of small interruptions of the direct rays, equally interspaced on a clear glass disc, the actual projective power of the beam is but slightly impaired, although of course the amount of light transmitted is reduced in proportion to the number of interruptions introduced. By "thinning out" the condensed rays in this manner, the character of the light transmitted is greatly modified. Its intensely dazzling effect is almost entirely eliminated, by reason of the fact that the collective effect of the group of obstructions in front of and quite near to the electric lamp or other source of light is partially to obscure such source from the view of anyone approaching from the opposite direction. There is also a marked increase in the extent of its diffusion along the whole length of the beam.

In designing the lamp glass, however, the writer recognised the desirability of

* Patent No. 169779/21.

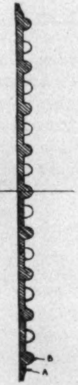
avoiding or at any rate minimising the loss of illuminating power resulting from placing in the path of the beam any group of substances of an opaque character. To effect this he has substituted, for opaque ray interrupters, a collection of small lenses of glass. These are of a special shape, somewhat resembling the ordinary bulls-eye lens but proportionately much thicker and of a more conical form. They are based on the surface of the clear glass disc, as shown in Figs. 1, 2, and 3.

FIG 1.



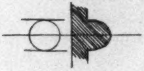
PLAN

FIG. 2



SECTION

FIG. 3.



ENLARGED PLAN & SECTION OF CONOID

SCALE OF INCHES

The apices of the small lenses described are, in fitting the glass in the lamp, caused to project inwards towards the source of light. Their general effect is to intercept a proportion of the direct rays, but these, being radially deflected through the curved surfaces, are concentrated on to the bases of the conical erections. Thus practically the whole of the light is made effective. The uninterrupted rays pass through the clear spaces between the small lenses, while those which are intercepted form on the external surface of the glass a number of small spots of light of intense brilliancy which are of high illuminating power and usefully reinforce the attenuated rays passing between them.

It is submitted that the degree of success to be anticipated from a lamp glass designed as stated must largely depend on the quality and clearness of the glass employed. In the model exhibited there are obvious defects which in the manufacture of the glasses in any quantity would be corrected. The surface of the glass on the side of the conoidal erections is of a granular texture, very obstructive of light, and the glass itself is much too thick. These are manufacturing defects which should be allowed for in any actual test of the model.

A NEW DESIGN OF MOTOR HEADLIGHT

By A. WHITEHEAD.

The essential differences between this lamp and an ordinary motor headlight with a paraboloidal reflector are:

1. The reflector is a deformed paraboloid. It is generated by spinning a parabola around an axis which oscillates a small amount during a part of the revolution.

2. The electric lamp has a very compact filament about 5 mm. long, wound as shown in Fig. 1. The close coiled end is situated, when the focussing is correct, between 4 and 5 mm. behind the focal point. The sides of the primary beam mainly originate in this close coiled part and hence the illumination is more uniformly bright across the beam than usual.

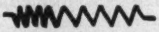
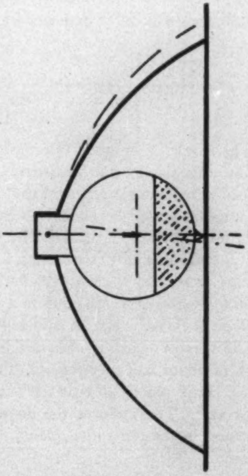


Fig. 1.



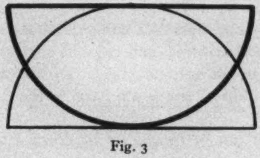


Fig. 3

Fig. 2

The general theory is that with an ordinary reflector and the bulb focussed as stated, neglecting errors of workmanship and the size of the filament in cross section, none of the reflected rays are convergent (practically) in front of the lamp. Hence the lower half of the reflector projects approximately a semicircular beam, the top boundary being flat and horizontal. The top half similarly projects a semicircular beam reversely placed. If the top half be rotated about the focal point, as shown in Fig. 2, the half beams can be made to lie on a distant screen as shown in Fig. 3. A split reflector, however, is unstable and much of the side light is thrown down more than necessary if the top half be inclined bodily. Hence the axis is oscillated in a special way to give a continuous reflector as shown in Fig. 2, and to make the united half-beams substantially lie in a semicircle, most of the intensity being near the upper horizontal boundary.

The front of the bulb may be coloured green (or any other suitable colour) to filter the direct light from the filament so that it will not blind oncomers closely approaching the lights, as in passing.

Thus this headlight gives not only the primary beam for distant projection but also a few feet ahead of the car wide spreading illumination direct from the source of light but softened by filtration through a coloured medium. Further the primary beam, which conveniently diverges about 1 in 8 on either side of the centre, can be projected so that its upper intense rays lie below a four feet or other specified level, yet give satisfactory illumination between that level and the ground for quick driving.

Reflectors and bulbs may conveniently replace those in existing lamps.

H. C. GIBSON'S ANTI-GLARE HEADLIGHT

By H. C. GIBSON.

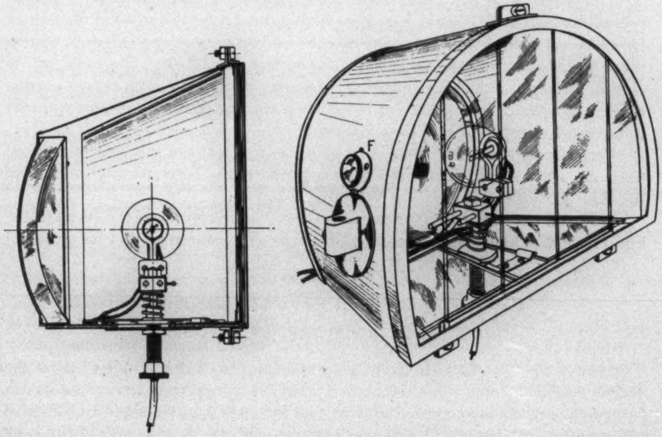
THIS headlight is designed to produce two important effects: (1) to illuminate the road at a distance of 120 yards from the car, and (2) to illuminate a large area of the road immediately in front of the car, and at each side. These effects are obtained with a minimum of dazzle and no rays of light are to be found at a greater height than 4 feet above the roadway. The road illumination 120 yards ahead is produced by an intense narrow beam having a very small angle of divergence in the vertical plane. For normal adjustment—i.e. on level roads—the axis of this cone of light is a straight line from the lamp to a point on the road about 100 yards ahead; but the slope of this axis can be adjusted easily from the driver's seat.

The narrow beam is obtained by means of a Mangin mirror having a focal length of about half its aperture. The source of light is a straight spiral filament electric lamp, placed so that the filament is horizontal and at right angles to the mirror axis. This reduces the dispersion in the vertical plane. To increase the dispersion in the horizontal plane, two cylindrical lenses are fixed to the front of the lamp.

As suggested above, the source of light can be moved up or down from the driver's seat so that the height of the beam may be adjusted to suit the various conditions of car loading, and the varying road conditions and inclinations—e.g. proceeding over the top of an arched bridge or the brow of a hill.

The illumination of the roadway in the foreground (and at the sides) of the car is obtained by means of a portion of a conical reflector round the top and sides of the source of light, the bottom of the lamp house being glazed. This foreground and side illumination is extremely good, and absolutely without any dazzling effect whatever upon oncoming pedestrians or other road users. This foreground illumination not only helps the driver, but it also has the effect of neutralising any accidental dazzle effect of the distance beam which may be caused by a bad bump over a pot hole, for even though such light might momentarily tend to dazzle a pedestrian or other user, yet the brightly illuminated roadway round about the front and wheels of the car would speedily show itself. A further advantage of this particular form of foreground flood light is that it does not blot out the vision on a misty night.

It is realised that in any lamp much glare will be obtained should the light source be out of its proper focus position. In this pattern a pin-hole "focuscope" has been fitted, in which a small image of the light is projected on to a small glass window on which is marked the correct position at which the image should appear for normal adjustment. This may seem to be troublesome, but it is almost an absolute necessity, owing to the fact that no two bulbs can be relied upon to have their filaments in exactly corresponding positions, and, further, because it is difficult to conceive of any automatic self-focussing source of light. The focuscope itself is extremely simple, and so is the process of adjustment of the source of light.



A REVERSIBLE MOTOR HEADLAMP

By A. A. SANDBROOK.

(Motor Lamp and Radiator Co.)

For normal running the lamp faces the front as is usual. When passing the oncoming traffic and it is desired to reduce the glare from the light, the lamp is entirely reversed by means of a Bowden wire and lever attached to the steering column; the lamp turns downwards on a coil spring, which also enables it to return to its normal position. The lens, which is in the back of the lamp normally, faces rearwards obliquely, the front of the lamp takes up the same position when reversed and throws the light towards the side rearwards, indicating the roadway quite clearly to the oncoming cars. Thus it is not necessary to switch the lights on and off, leaving the drivers in complete darkness, as simultaneously the rear bull's eye appears in place of the disappearing rays from the front of the lamp.

It may be desirable to provide a disc to fit on the front of the lamp so as to cut off a portion of the light projected to the rear for town driving, that is, when the powerful light is not needed. The lamp bulbs are run at 12 volts.

THE NO-GLARE LAMP

By W. F. HOARE WARD.

The principle of the lamp is in utilising the centre of a parabolic or other similar reflector (which in all existing lamps has been cut away for purposes of focussing), by mounting the bulb in front of the reflector and providing for all kinds of adjustment (horizontal, vertical, etc.) to ensure the true focus being obtainable and to control the angle of the beam, either cutting away or blacking out a certain portion of the lower part of the reflector so as to cut off any rays directed upwards and only utilise those giving a forward parallel beam.

Experiments prove that there is no glare at 150 yards and it is easy to see four telegraph poles ahead. The lamp gives a good driving light directly in front of the car; the width of the beam at 150 yards is 40 feet.

Provision has been made for carrying a spare bulb in front of the lamp, as the bulbs require to have special focussing filaments. [Provisional application granted.]

THE BLACKMORE ANTI-DAZZLE DEVICE

By F. R. BLACKMORE, A.C.G.I., B.Sc.

The device consists of a reflector of proper design placed in the upper half of the ordinary parabolic reflector in use on motor car headlamps, their reflecting surfaces being opposed. The front reflector is formed by cutting a paraboloid in half by a plane containing the axis. Its dimensions vary with the focal length of the back reflector to which it is to be fitted. The front reflector is placed in the lamp so as to be co-axial with the back reflector, its lower edge just hiding the filament of the lamp, thus obviating the possibility of direct rays from the filament reaching the eye.

In order to obtain a divergent beam the filament must of course be behind the focus of the back reflector. This causes dazzle by the intensity of the light which reaches the eye from the upper half of the reflector. The device under consideration collects this light and redirects it in a useful direction, viz. on to the surface and sides of the road and into the beam thrown ahead. The rays which would cause dazzle (when no part of the filament is in front of the focus), as shown in Figs. 1 and 2, are therefore trapped and redirected so as to intensify the light where required, no light at all being sacrificed. All rays which reach the lower half of the back reflector directly from the lamp are thrown downwards by virtue of the fact that the beam is divergent.

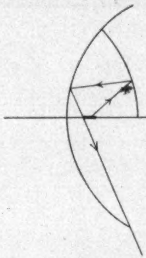


Fig. 1

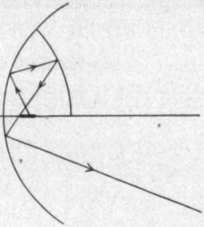


Fig. 2

A wise choice of filament is, of course, essential and it is obvious that the best results will be obtained from one which lies as nearly as possible along the axis.

The Electric Repair and Lighting Co. of Reading, has now completed arrangements for the production of the device, which is provisionally patented and can be fitted to any standard electric headlamp.

SIMPSON'S PATENT ALL-BRIGHT ANTI-DAZZLE

By H. J. SIMPSON.

THE function of this device is to overcome the spreading of the rays from ordinary motor car and cycle headlamps, whether acetylene or electric. It consists of a number of plated slats, of prismatic cross-section, arranged at such an angle that the upward rays from the reflector are reflected from the inner face of one slat to the outer face of the neighbouring slat and thence in a horizontal direction outwards. The slats extend a fraction of an inch below the optical axis of the lamp and an additional thin slat is fixed near the bottom of the lamp so as to deflect the upward rays from the bottom of the reflector on to the road. The slats are carried in two plated vertical members which also serve to reflect the side rays on to the slats and thence forwards.

With this anti-dazzle there is no direct glare to "blind" temporarily the vision of either drivers or pedestrians. No dimming switches are required and there are no levers to attend to.

The device tends to increase slightly the amount of light thrown on the road. It is very simple and can be made to fit any size or type of headlamp.

DESCRIPTION OF KENT'S GLARE GUARD

By Messrs GEORGE KENT, Ltd.

This consists of a rectangle of glass of a smoked blue tint that effectually shades the eyes from the blinding rays of headlights. The glass is held in a frame which pivots about the upper edge, and is clipped to the glass or beading of the wind-screen before the driver. The correct position for the guard is slightly to the right of the driver's line of sight when looking ahead and the recommended method of using the glare guard is to keep it interposed between the eyes and the headlights of approaching cars while at the same time looking past the guard, not through it, at the road ahead.

The Royal Automobile Club Demonstration No. 6 proved that the use of the guard increased the "no-dazzle" space between the offending lamps and an approaching driver from 129 feet to 268 feet.

DISCUSSION

Commander T. Y. Baker: As Mr Walsh has so clearly stated in his paper, the problem of the motor headlight is two-fold. The motorist needs enough illumination to light up obstructions in the road for a sufficient distance so that he may pull up in time; the pedestrian, the man on the push bicycle, or the driver of an opposing car does not want to be dazzled by the glare. The driver needs at least 3000 candles, the man in the other car is blinded by less than a quarter of this.

I think it may be stated without fear of contradiction that the man driving behind the headlights has received from inventors and designers much more attention than the victim of glare. The natural candle power of lamps and the efficiency of reflectors have been increased to such an extent that it is now a common occurrence to meet upon the road cars with headlights whose effective candle power in a horizontal direction is ten to fifteen thousand. In only a minute fraction of the number of lamps of this character is there any attempt to keep the glare effect below the horizontal and my own experience of having to drive a small car fifteen miles every day after dark during the winter months on one of the main roads out of London is that with private cars and motor bicycles coming in the opposite direction one is dazzled by the light from 80 per cent. of them; with commercial vehicles, which, as a rule, do not travel more than eighteen miles per hour, the proportion of dazzle headlights is probably not one in ten.

In using the term dazzle in this connection I give it a very definite meaning, namely, that my acuity of vision is so impaired that I could not see a man step off the pavement in front of my car in time to pull up unless I were going dead slow. Of course even in day time if a man steps off the pavement just in front of my car I can see him but cannot pull up in time but if he does so, say, twenty yards ahead of me, I can either pull up or avoid him. If he steps into the road at night time just in front of my car I may see him but cannot avoid him, but if he is twenty yards ahead of me I shall not avoid him because I cannot see him, being blinded by the opposing car.

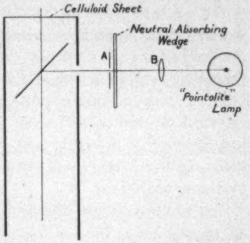
In addition to the danger of my car to the pedestrian when I am dazzled by an opposing car, I am also in danger myself, for unless my headlights are equally powerful I cannot see the kerb of the road and have to drive by faith rather than by sight.

My own impression is that by far the greatest number of accidents that occur are due to these two causes. The man with powerful headlights never comes to any harm and never runs anybody down, but it is he who is indirectly responsible when another car runs from behind into a man on a push bicycle. I have felt this so keenly from my own experience upon the road that I should be only too thankful if some really efficient headlight could be designed and I have no hesitation in saying that if this can be done the pedestrian upon the road has the right to insist upon immediate legislation to make such lights compulsory.

As matters are at present, the driver of the small car more than any other user of the road is at the mercy of the night hog who insists on going forty miles an hour. The latter gets his high speed with safety; the former must almost stop or meet with an accident. The fact is that the man with the powerful headlights is getting more than his fair share of the amenities of the road and if we have legislation to restrict the power of his lamps and so compel him to go slower in his own interest such legislation will not be reactionary but will merely be restoring to the many what has been filched from them by the few.

Previous to the meeting I was not aware of the amount of work that had been done in connection with the more theoretical side of the problem and, being in ignorance of previous work, Mr R. W. Cheshire and I set about finding out for ourselves what quantity of glare or dazzle was the maximum that could be supported. Our experiments were conducted in a darkened room in the following manner.

A wooden case about 3 ft. 6 ins. in length and 9 or 10 ins. square cross section (see figure) had one end covered with a semi-transparent sheet of white celluloid and the other end open. Inside the box a sheet of plate glass was fixed at an angle of about 45° with the axis of the box and a "Pointolite" lamp was placed outside as shown. An image of the light was formed at *A* close to the box by means of a lens *B*. A small hole cut in the side of the box enabled a reflection of the image to be seen by an observer looking into the box while at the same time *through* the glass plate he could see the celluloid background which was faintly illuminated from the outside. We had means of adjusting this external illumination and also we had means of varying the effective candle power of the light by means of an absorbing neutral wedge at *A*.



The image of the headlight appeared approximately to be upon the celluloid background and at its centre. Tests were carried out of the ability to recognise the position of a small black disc which was held up against the outside of the celluloid. With no headlight showing there was no difficulty; the disc could always be recognised. With a powerful light the disc could not be seen at all and intermediately there was a strength to the headlight that just enabled the position to be located with certainty. The disc positions were always about 3 ins. from the headlight, i.e. 5° away as seen by the observer. The intensity of the background illumination was from 0·02 to 0·03 foot candle, a figure that appeared to us to represent the general illumination of the background for a man in a car with only feeble headlights, or perhaps nothing but sidelights.

Variation in the intensity of the headlight was made until the observer could be just sure of all positions of the movable disc; we found that we were both in close agreement with one another and that the headlight must not exceed about 0·8 candle power.

Now some sort of convention must be made when we try to translate this into practical requirements. When the opposing car is a long way off the dazzle effect is small. When it is quite close the glare is from the side and does not cause inconvenience and there is some intermediate distance at which the effect is worst and for which limits to the candle power ought to be set. I should myself choose 100 feet as that distance, with a mental reservation that it might be necessary to reduce to 50 feet. For the hundred feet separation between my car and the other one I can afford to be temporarily dazzled; the other car will be beyond the dazzle area in a second and then I shall be able to see again. In that second there is not much time for any one whom I cannot see to step in front of me, or for me to drive into the pavement. At 100 feet, light of 650 candle power has the same effect as one of 0·8 candle power at 3 ft. 6 ins. Hence 650 candle power must be the maximum light that can get into my eye at that distance and in a direction therefore of about 1° above the horizontal.

Such a figure is only rough. It is based on experiment on a small scale, and takes no account of the roughness of the road, of the bad loading of the car, bad adjustment of the headlight, etc., and taking all things into consideration it is more likely to be too high than too low. If, however, we accept that figure we have a guide immediately to the manner in which headlight legislation should be framed. There should be no candle power exceeding 650 visible in a direction just above the horizontal when the car is standing on a level road.

Inequalities of the road, hills and hollows should be dealt with by allowing just enough light below the horizontal to permit him to drive at a reasonable speed. Mr Walsh has stated that the driver needs 3000 candle power in a direction half a degree below the horizontal in order that he may be able to recognise a person moving at 100 feet and with that figure I agree.

To sum up I think that headlight legislation will have to come. I think that its main outlines will involve a reduction in the power of headlights below what is prevalent nowadays and that in detail it should specify a maximum of 650 candle power above the horizontal and 3000 or perhaps 5000 candle power below the horizontal. I do not consider a three-quarter beam practicable in England where no road is straight for any distance.

Dr S. W. Stratton (Director, Bureau of Standards, Washington): 1. The Bureau has not recently made any investigations of the subjective or ophthalmic aspects of "glare," and we are therefore not in a position to contribute any new ideas to this phase of the problem.

2. We have been making some tests of automobile headlight devices, but these tests have been largely for the purpose of determining whether or not certain types of devices comply with the requirements which have been established in a number of States in this country. Since the authority to adopt and enforce such regulations is vested in our State officials rather than the National Government, there is considerable diversity between the different States, and our efforts have been directed largely toward the adoption of reasonable and practical requirements with as great a degree of uniformity as is feasible considering the different conditions to be met in different parts of the country.

3. I believe it is rather generally accepted that the fundamental condition of glare is excessive brightness contrast, and therefore the nature of the background or general surroundings has as much to do with determining whether or not a given source will be glaring as does the light source itself. In the case of motor lights on unlighted highways the general background is so dark that headlights are almost inevitably dazzling even if the candle power is very low in the direction of the observer. This condition would seem to indicate that practically all light above the horizontal plane from the headlights should be prohibited. Such a regulation would, however, disregard entirely the needs of the driver of the car on which the headlights are placed, and would give rise to more hazard than would result from a moderate amount of glaring light above the horizontal. In other words, it is necessary to consider the vision of the driver of the car as well as of those who have to face the car.

4. The conditions stated above indicate that practical requirements for headlights must of necessity be reached by a compromise. It is on such a basis that the requirements in this country have been developed. The essential requirements are two. One of these is that the driver must have enough light on the road to enable him to see fairly well. The second is that the light above the horizontal should be kept low enough in candle power to be tolerable for those who must face the headlamps. The general procedure in this country has been to adopt laws

and ordinances stating these two requirements in general terms, and to authorise the executive officials to adopt specific requirements which are intended to embody these general principles. In order to arrive at specific numerical values for such regulations, many road tests have been carried out. Most of these tests have been arranged under the auspices of the Illuminating Engineering Society working with the cooperation of the Society of Automotive Engineers. This Bureau has been represented on the committee which has managed the work, and we have in general believed that the results obtained were reasonable.

5. The specifications which were adopted some years ago and also the most recent revision of the numerical values which was published only a few months ago are included in two Reports* of the committee mentioned. Three States in which automobile traffic is rather heavy are using the new specifications, and it is probable that they will soon be adopted by a number of other States.

6. As you are probably aware, this problem was discussed at the meeting of the International Commission on Illumination in Paris last summer. The Commission reached no conclusions regarding the requirements which should be established, but adopted resolutions urging that action in the different countries be deferred until agreement could be reached so as to make the regulations finally adopted uniform. The Commission also appointed a committee to consider the problem and report at the next meeting of the Commission. The chairman of this committee is Dr Clayton H. Sharp, of the Electrical Testing Laboratories, 80th Street and East End Avenue, New York City. In this country the situation is somewhat complicated by the fact mentioned above that there is no single authority which has jurisdiction, and that each State acts more or less independently on such matters. The problem became so pressing several years ago that it was out of the question to defer action until a uniform regulation could be agreed upon. Moreover, since the United States of America is so remote from European countries, it does not appear to be particularly important to have the same requirements in force here as on the other side of the Atlantic. There is naturally more reason for having uniformity in countries between which there may be considerable motor traffic. Although the conditions make it less important to have the American requirements similar to those used in Europe, we shall, of course, be very glad to have the benefit of discussion and experience abroad, and shall be much interested to learn the results which may be brought out by the meeting.

Mr Leon Gaster expressed his appreciation of the invitation conveyed by the Optical Society to the Members of the Illuminating Engineering Society to be present at this discussion.

The subject of motor headlights, especially with regard to preventing dazzle, had been brought prominently before the public of late and, as Mr Walsh had mentioned, the Illuminating Engineering Society had held a number of discussions from 1911 onwards dealing with headlights in relation to traffic. In addition to Dr Hickman's paper in 1911, he (Mr Gaster) would like to refer those present to Mr Walsh's own valuable contribution in 1920, and to the supplementary paper by Major Garrard, which was read about a year later. These discussions had culminated in a joint committee on which the following bodies were represented: The Illuminating Engineering Society, The Royal Automobile Club, The Research Association of the British Motor and Allied Manufacturers, The Institution of Automobile Engineers, The British Scientific Instrument Research Association, The Commercial Motor Users Association, The Electric Lamp Manufacturers Association of Great Britain, Ltd., The Council of British Ophthalmologists, and The Physiological Society.

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* *Trans. Illum. Eng. Soc. N.Y.* June 10, 1920; Feb. 1922.

He felt that the Optical Society could render valuable aid to this Committee in connection with the optical problems involved, and he took the opportunity of conveying an invitation to the Society to appoint a representative to act on this Joint Committee.

He proceeded to refer to the experience of other countries in which the question of regulations for motor headlights had been receiving attention. A great deal of valuable work had been done by the Illuminating Engineering Society in the United States and he would like to select for special reference the specification, which that body has recently issued, describing the tests that a headlight should undergo in order to meet modern requirements. He observed that the German Illuminating Engineering Society had also been discussing the problem; one interesting suggestion had been that a distinction should be drawn between "glare" that merely caused temporary discomfort and the "glare" that was actually intolerable, forcing persons who encountered it to turn away their heads, and shut their eyes. This latter severe form of glare should certainly be eliminated in motor headlights.

The fact that regulations for headlights had now become a matter for consideration in all countries where motor cars are widely used, was illustrated by the special importance attached to this subject at the first technical session of the National Illumination Commission held in Paris in July last year. Mr Walsh, in referring to this meeting, had mentioned the resolution taken on that occasion to appoint an international technical committee to review regulations on headlights in the various countries with a view to future common action. He might add that Major Kenelm Edgcumbe was the official representative of this country on the Committee.

He remarked that the problem of legislation was a complex one, and in view of the very large number of headlights already in use it was desirable to suggest means of avoiding "glare," which could readily be applied to existing apparatus. Naturally any regulations would require modification from time to time; for instance, the understanding that a certain illumination should be available at a precise distance from the car assumed that the car could safely pull up in this distance when travelling at its maximum speed. When the speed limit was relaxed it might be necessary to provide for effective illumination at a greater distance ahead of the car.

In conclusion he added that, as Mr Walsh had stated, the problem resolved itself into a compromise between the requirements of the driver and the pedestrian or the driver of an approaching vehicle. The best solution could only be attained by examining the problem from every point of view, and by enlisting the help of the various experts concerned, as they aimed at doing on the Joint Committee appointed by the Illuminating Engineering Society. It was also hoped that the Committee would act as a permanent source of information, keeping in touch with all new developments, so as to act as a useful link between official legislation and public requirements.

Mr J. S. Dow endorsed Mr Gaster's statement as to the need for research on the design of headlights. It was now generally agreed that the most important element in causing glare was excessive contrast. A headlight which was innocuous in a brightly lit thoroughfare might be very glaring in a dark lane. Accordingly headlights and public lighting should be considered conjointly. He believed that a method of distributing light over the surface of the car from concealed lamps, so as to enable its outlines to be more clearly seen, had been tried. This would have a useful effect in reducing the contrast between the brightness of the headlight and its immediate surroundings, as well as assisting the perception of the car at a distance. Another factor that seemed to deserve study was the colour of the light. It had been stated that a slight yellow tint, involving the elimination of the violet, but only small loss in the total light, was favourable to definition of distant illuminated objects, and also tended to diminish the inconvenient luminous haze formed in front of a headlight in misty weather. According to a paper read before the German Illuminating Engineering Society the use of a yellow screen also allowed a higher intrinsic brightness to be attained before the point of intolerable glare was reached.

It was difficult to devise tests of illuminating power and glare which were at once sufficiently accurate and capable of being applied on the road. For this reason he preferred accurate laboratory tests. If such tests could be agreed upon by leading technical bodies and certificates issued to those who voluntarily submitted headlights for tests, this in itself would tend to raise the standard of design, and bring about an appreciable improvement.

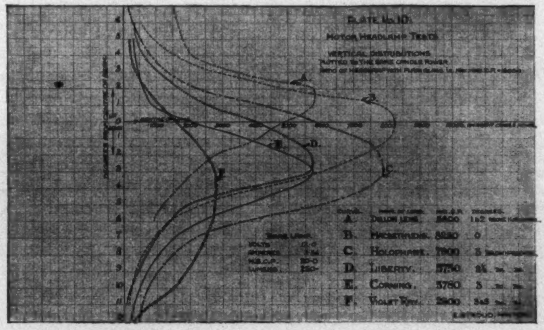
Capt. E. Stroud: The problem of glare from motor headlights is one of great importance to all users of the high road at night. It is undoubtedly a pressing necessity to eliminate the dangerous blinding glare from powerful headlamps and to restrict their use to their proper function, that of illuminating the roadway for safe driving.

The elimination of glare with the provision of an adequate driving light is not an easy problem to solve, and there are many conflicting factors to consider. First, one must have sufficient forward intensity to see far enough ahead for safe driving. Furthermore, this necessary intensity depends to a great extent upon the speed of the car. It has been proved that the need for further light above the horizontal beam is rapidly more urgent for safety at speeds above 20 miles per hour. Another important factor is atmospheric conditions, and again there is variation among drivers as to vision. Besides having sufficient forward light to drive safely, we must have sufficient spread of light to see road boundaries, ditches, corners, etc.

The majority of anti-glare devices, other than those which take away most of the main forward beam, have too restricted a beam to be a really satisfactory solution. Again the main beam must not be of such a height as to glare the eyes of the drivers of on-coming vehicles as is the case with the majority of our present day headlights.

In the discussion, however, a correct definition of "glare" was given, but I should like to give a much more concise definition of glare so as to get down to bed rock. Glare in this connection is simply contrast, and I believe if a means were adopted of reducing the contrast of the bright headlights and the dark surroundings, much of the trouble would be eliminated. If, for instance, the car itself were illuminated more or less on the flood light principle, much glare from the headlights would be eliminated. This, I think, would not cure the trouble, but coupled with the modifications of the beam by means of devices which are at present on the market for diffracting the main beam two or three degrees, it would be the practical solution.

Some time ago I made a series of tests on various anti-glare devices as used and passed by law in America. These tests, which show the vertical distribution, are all of devices which employ lens glass fronts for the distortion of the beam from the standard headlamp. In the majority of the curves obtained (see figure) the main beam is diffracted from 2 to 3 degrees below the horizontal, which is the correct amount. In the case of the headlight lens in which I am particularly interested—the Holophane—it will be seen that the main beam is diffracted from 2 to 3 degrees below the horizontal with suitable diminution above, but what is of as great importance, but not shown on the vertical distribution curves, the sideways spread is sufficient to negotiate the side hedges and passing vehicles with fair safety.



In driving at night, one can do with pretty well as much light as one can get, and I think it would be a hard task to rectify the trouble unless legislation is passed compelling cars to adopt certain means.

Mr F. Peake Sexton: The avoidance of glare in motor headlamps is a matter of considerable importance and paramount difficulty as is testified by the diversity of the specifications issued. That an optical system can be made to fulfil almost any condition was shown by the admirable lamp designed by Sir Howard Grubb and so explicitly explained by Sir Wm Barrett. Yet the average motorist does not take kindly to these lamps owing to increased cost and the necessity for using the correct bulb in the correct position; probably the latter is the more serious objection, as the setting or the focussing is really a technical matter, although simple to the experienced.

Many designers of these anti-glare lamps appear to do little more than distribute the light below the horizontal axis of the lamp by a more or less complicated lens system, although in many cases the same effect could be more easily obtained by the simple device of tilting the lamp, that is giving it an inclination to the road.

The writer is of opinion that in order to reduce glare to the minimum it will be necessary to arrange for the illumination of the road abreast of the car and a little to the rear, and thus reduce the glare effect by contrast. This method would render the meeting and passing of cars much safer than any of the present schemes, but would mean a considerable increase in the battery power of cars. This, however, should not be a serious difficulty as, if car owners can afford enough power to dazzle the other users of the highway, it seems the least that can be asked that they use a small extra amount of power to overcome the danger caused by themselves. In addition to this side illumination it will also be necessary to enforce some specification such as that of the Massachusetts State for the headlamp illumination.

Another point that is rarely considered with reference to the question of glare is the curvature of the road in its linear direction, for it must naturally mean that every change of gradient causes a breakdown of our carefully calculated illumination, such as is seen when a car ascends and rides over the crest of a bridge.

The question of swivelling headlamps has been often considered, but the writer is still of opinion that their use would add to the safety of the public and the comfort of the driver. This point comes into the present discussion, as illumination planned for a straight road fails at curves or turns.

Dr R. S. Clay thought that motor headlights should be tested on a laboratory basis and certificates issued. He asked whether the committee mentioned by Mr Gaster would consider the proposition.

Mr Gaster, in reply, suggested that, after a specification had been drawn up, suitable tests might be carried out at the National Physical Laboratory.

REVIEW

The Physical Society of London: Report on Series in Line Spectra. By PROF. A. FOWLER, A.R.C.S., F.INST.P., F.R.S. Pp. 182; 12 figs. and 5 plates. (London: Fleetway Press, Ltd., 3–9, Dane Street, High Holborn, W.C. 1, 1922.) Price 12*s.* 6*d.* Post free, 13*s.* Bound in cloth, 15*s.* 6*d.* Post free, 16*s.*

There has, perhaps, been no branch of Physics for which a comprehensive account has been more urgently needed than the Laws of Spectrum Series. This need has been met in Prof. Fowler's Report with a unique success which could only be expected from one who has himself made such notable contributions to our knowledge of the subject. The Report is divided into two parts and in the first is given a general account of the relations in spectrum series beginning with a historical note on the early development of the subject. It would obviously be useless to give a complete summary of all the work that has been done, but a connected and concise account has been given of everything of importance, and the Report is fully illustrated with figures and diagrams which are particularly helpful in making clear some of the more obscure relationships. A chapter is devoted to the application of the Quantum Theory to spectra and a discussion of the most recent theoretical developments. In the second part of the Report are given tables showing the experimental results which have been hitherto obtained for the different elements. The arrangement of the tables leaves nothing to be desired and references to the original papers are given throughout. In cases, e.g. Paschen's work on the spectrum of Neon, in which the results are not given in full, an account is given which shows without redundance the character of the result obtained and serves as a guide where a further study of the original paper is required.

There are five excellent plates illustrating typical spectra discussed in the text. The value of this Report is two-fold. It represents the first connected account of a subject the fundamental importance of which, in relation to the structure of the atom, is now fully recognised; but perhaps its greatest importance lies in the new developments and advances which will follow. The physicist can now find at once in an accessible form not only what is already known, but also where the gaps in our knowledge lie and what is awaiting further investigation.

T. R. M.

ABSTRACTS OF PATENT SPECIFICATIONS

176456. British Thomson-Houston. REFLECTORS.

A glass former is first chemically coated with silver, and layers of silver and copper successively are then electro-deposited upon it. The whole is then backed with cement, and if necessary, a metal shell. It is then stripped from the glass, preferably by the use of jets of compressed air, and a layer of transparent lacquer applied to the face.

176843. Miller, J. M. SEARCHLIGHTS.

The movement of a sighting-telescope brings into action one or other of two electric motors, which gear with opposite sides of a differential gear, so that the searchlight is caused to follow the movement of the telescope.

177045. Orr, A. E. OPTICAL PROJECTION-APPARATUS.

A series of lantern slides, hinged together to form a continuous strip, are passed successively through a frame in front of the lens, and stacked upon a receiving tray. The movement is effected by an operating bar, connected to two levers, by which alternate slides are respectively engaged, withdrawn, and folded down.

177049. Carrie, J. GRINDING AND POLISHING GLASS.

The rubbers are given a planetary motion, and the work is carried upon a table, which is reciprocated beneath them. The load is controlled by a movable pressure head.

177192. Proctor, D. B. PROJECTION SCREENS.

The fabric is secured to a rectangular frame by tapes passed through a series of holes, arranged upon arcs of circles struck from the centre of the projection lens. The screen may have a mercerised or sateen face, or be made from silk interwoven with jute.

177243. Hugershoff, K. R. STEREO-GRAMMETRIC APPARATUS.

This apparatus is arranged to trace out contour lines upon a chart, making use of two photographs of the area taken from different arbitrary points. Two telescopes, fixed in direction, are pointed towards carriers upon which the photographs are mounted, and adjustment is made to suit the points from which the photographs were taken. Subsequent movement of the carriers to centralise corresponding points of the two images are transmitted through a pair of arms to a marking point, which traces out the required lines.

177414. F. Bateman & Co., Ltd. and another. COMPARING LENSES.

A bar carries a lamp at one end, and a screen at the other. At an intermediate point there is placed a frame, rotating about a vertical axis, and intended to receive two lenses of equal power. By alternate observation the image from, say, a bi-convex lens can be compared with that from a meniscus.

177575. Hill, H. W. SURFACING LENSES, ETC.

The tool is moved over the work in a constantly-varying curved path. A main driving-wheel gears with two others, having unequal numbers of teeth, and each fitted with a crank-pin, the throw of which can be adjusted. Two connecting arms are operated by these crank-pins, and are pivoted together at their outer ends, upon which the tool is mounted.

177918. Terry, A. E. VEHICLE LAMPS.

To prevent glare, the headlights of a motor vehicle are mounted behind the honeycomb radiator, so that the light passes through the tubular air-passages.

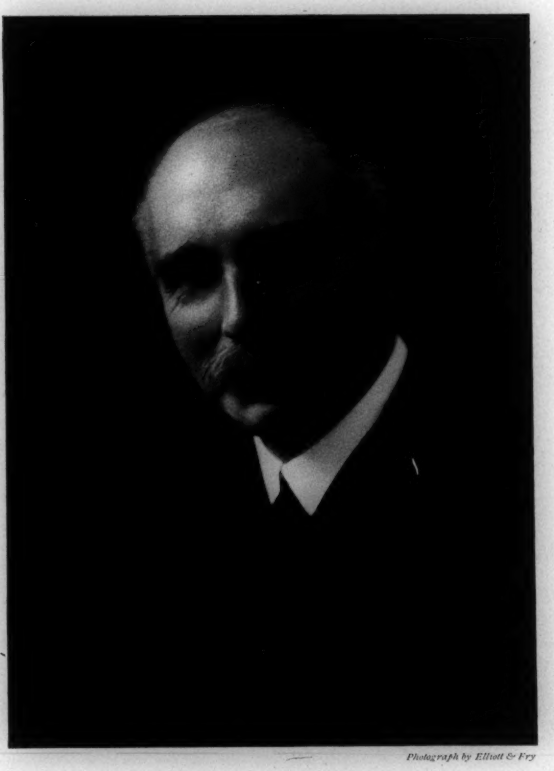
178107. Zeiss, C. MICROSCOPE CONDENSERS.

The lower, or parabolic reflecting member of an immersion condenser for dark ground illumination is formed with a hollow in its upper surface, substantially concentric with the lower surface of the upper, or lens, member, so that it is separated from it by an air-gap, across which the light passes substantially normally. The lower member is adjustable by rotating its screwed cell in the main mount, a projecting lever being provided for this purpose, so that the illumination may be adapted to suit slides of different thicknesses.

178136. Harrison, H. T. PROJECTION APPARATUS.

The arc carbons are placed vertically, and below them is arranged a condensing ellipsoidal reflector. The beam is then directed towards the screen by an inclined mirror, placed so as to intercept the light either before or after it passes the projector lens, which in the latter case is, of course, arranged vertically.

R. J. T.



Photograph by Elliott & Fry

ROBERT S. WHIPPLE
PRESIDENT OF THE OPTICAL SOCIETY
1920–22